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MILITARY ESSENTIALITY IN INVENTORY MANAGEMENT

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SUBMITTED IN PARTIAL FULFILLMENT OF

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IN

OPERATIONS ANALYSIS

UNITED STATES NAVAL POSTGRADUATE SCHOOL

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ABSTRACT

The essentiality ranking of stock items is a universal unsolved problem in inventory management. The role played by essentiality factors in mathematical inventory control models is discussed. Several methods for item essentiality ranking in present military use are described. A proposal is set forth to accomplish military essentiality ranking by statistical examination of the numerical priorities assigned to requisitions for each item. The characteristics of the U. S. Navy priority system which give justification to this proposal are pointed out. A limited experiment is described wherein the essentiality rankings produced by the proposed system are compared with those produced by Stanford Research Institute's essentiality formula in use at the Electronics Supply Office. The experiment, involving a small homogeneous sample of electronic tube items, indicated agreement (in the sense of positive correlation) between the results produced by the two systems. A more complete experiment with a more heterogeneous sample of items is recommended.

SUMMARY

The U. S. Navy is increasingly interested in the use of mathematical inventory models, programmed into high speed digital computers, for the inventory management of Naval material with statistically predictable demand rates and delivery lead times. Many such models exist, the more useful of which contain a "penalty function", which penalizes the inventory manager for stock shortages. Almost a universal requirement of these penalty functions is some "relative essentiality factor" such that the inventory manager is penalized more severely for stockouts of more essential items.

Several methods are practiced at this time for the ranking of inventory items by military essentiality, falling roughly into three categories:

1) Ranking based on studies performed at Supply Demand Control Points (SDCP) and Navy Department Bureaus by technical experts.

2) Ranking based on questionnaires answered by maintenance technicians or technically qualified officers in the field.

3) Formula ranking, backed by rationale, based on readily identifiable characteristic of a specific item such as its price, demand rate, weight and cubic dimension.

In categories 1 and 2, all methods studied involved the determination, somehow, of the importance of a given part to some Naval equipment.

Objections to the methods embraced by categories 1) and 2) above include:

1) The problem of multiple application - if a part is used in more than one equipment, what shall be the basis for its essentiality index?
2) In the case of category 1), technical personnel in the high supply echelons are far removed from the scene of equipment use.
3) They are expensive in terms of man-hours. Each part must be actively and separately studied, usually by a team of personnel.
4) Available results have proved to be useful primarily in the field of repair parts allowance list development

that it lacks firm theoretical or intuitive foundation.

It is argued that the requisition priority system in use in the Navy today represents a continuous, Navy-wide field review of the essentiality of Naval items. It is therefore proposed that the reporting systems of the LDCPS be augmented so that the priorities assigned to demand documents are reported along with other transaction information. Periodically, some function of the numerical priority designators assigned to requisitions for each item can be computed by high-speed digital computer and used as a relative military essentiality index. The function treated in this paper is the arithmetic mean.

A limited experiment conducted at the Naval Supply Center (NSC) Oakland with several items of electronic tubes indicated that 1) the information required to invoke this proposal is available on a system-wide basis and 2) there is a positive correlation between the results produced by the proposed method and the ranking produced by the NSC essentiality formula.

The items in the experimental sample are all electronic tubes with high demand rates.

for specific equipments or weapons systems, and not for Navy-wide inventory management.

The Navy seeks a method of the category 3 type, so that the ranking of items by military essentiality can be accomplished easily and cheaply, without study by teams of experts. One such is in successful use at this time. At the Electronics Supply Office (ESO), the Stanford Research Institute (SRI) inventory model contains an item balance factor

$$E = \frac{C}{\sqrt[4]{CD}}$$

Where C is item cost and D is its weekly demand rate. The C in the numerator is rationalized by the argument that cost varies with value or essentiality. A function of demand in the denominator is justified by the argument that fast moving items are staple merchandise, whereas equipment design and testing is directed toward slowing the demand rate for essential material. The exact form of the function E was developed by demanding that the formula produce rankings of the right order of magnitude for use as a parameter in the ESO inventory model.

The serious objection to this formula is

It is recommended that a new and larger experiment of the same type be conducted using items which are more obviously distinguished from one another from an essentiality standpoint, with a broader range of demand rates, and using data from many supply system sources.

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PART I

INTRODUCTION

The management of inventory by mathematical model is a relatively new and increasingly important area of interest for the operations analyst. In any enterprise which stocks materials for later use or sale, two fundamental management decisions must be made concerning the stock of each item: At what point of stock depletion should the stock be replenished? How many units of the item should be procured?

The traditional means of reaching these decisions is the exercise of human judgement by a stock reviewer. However skilled and energetic this reviewer may be, the process is typically slow, expensive, and susceptible to human error. Electronic data processing has, in the last several years, provided the reviewer with up-dated demand and issue data, but the stock reviewer remains the human bottleneck in the inventory decision process, at least for those items subject to statistically predictable demand rates and delivery lead time.

It remains for the high-speed digital computer, programmed in conformity with some acceptable mathematical inventory model, to

assume the stock review function in the case of items susceptable to this manner of control.

The United States Navy maintains inventories of stocks exceeding five billion dollars in value divided among more than a million items. [1] Most of these items can be considered to have statistically predictable demand rates and delivery lead times. Accordingly, the Navy, along with the several civilian operations research firms under contract for this work, has been a leader in the development and use of modern, high-speed inventory management technique.

The senior of the two authors of this thesis, a Naval Aviator, became acquainted with and interested in the field through study of a report by members of the Economics Division of Stanford Research Institute which proposed a mathematical model for inventory management of aviation repair parts. [2] Although this model was finally placed into use, in modified form, for electronics repair parts rather than for aviation materials, this interest continued. [3]

The junior author is a Supply Corps Officer with considerable past exposure to the management problems of large-scale inventories.

After discovering a community of interest

in this new field, the authors requested and received temporary duty orders to Stanford Research Institute for the summer of 1960 to study the work in progress there for the Electronics Supply Office. [4] While working at SRI under the direction of Dr. F. W. Dresch, Manager of Industrial Operations Research, the authors became interested in one of the thus far unsolved problems of the project: The provision of a numerical index reflecting the <u>MILITARY ESSENTIALITY</u> or <u>MILITARY WORTH</u> of an item for inclusion as an essential and critical parameter of the SRI Model.

In common with other relatively sophisticated models for inventory management, the SRI Model contains a penalty function which levies a "charge" against the supply manager for failure to meet demand for an item. It is only reasonable for the supply manager to expect a penalty which varies directly with the harm done to the consumer by this failure to supply. What is required is, therefore, some index or parameter of the penalty function which distinguishes the military importance of a given item from that of other items, penalizing most severely for shortages in items which can cause

a fleet unit to fail in or to abort its mission.

The problem here is no more than a specialized application of the broader study of utility theory.

Interest in this particular aspect of the problem led to a study of the efforts of Navy Supply Managers, of other armed forces, and of civilian practitioners directed toward the "worth-ranking" of inventory items. The results of this study are reported in Part II of this thesis. The authors were aided in this work by Dr. R. H. Davis of Stanford Research Institute and by Commander W. L. Wilkenson U. S. N., of the Logistics and Mathematical Statistics Branch of the Office of Naval Research.

Growing familiarity with the problem then led to a proposal by the authors of a method for essentiality-ranking of specific stock items based on an analysis of the priorities assigned by fleet units to requisitions for these items. The authors were assisted in the formulation of the proposal by Dr. S. G. Allen of Stanford Research Institute and by the supply staff of the Naval Air Station, Moffett Field. This proposal is advanced as Part III of this thesis.

An experiment was conducted within the Ships Supply Depot, Naval Supply Center, Oakland, for the purpose of confirming the reliability and practicability of the proposal. Funds for the experiment were granted by Rear Admiral R. J. Arnold, SC, USN (now retired). The initial "pilot" data were gathered by the authors, assisted and advised by Lcdr. S. D. Frost, SC, USN, a graduate student at the Stanford University School of Business and an experienced supply officer. Subsequently, data gathering was performed by Mrs. June Lanesse and Mrs. Aline Haake, under the direction of Mr. T. F. Bailey, Stock Control Supervisor, Ships Supply Depot, Naval Supply Center, Oakland. The results of this experiment are reported as Part IV of this thesis.

Part V of this paper contains the detailed conclusions and recommendations drawn by the authors from their work on the problem to this date.

Prof. F. F. Sheehan, of the Naval Postgraduate School, has generously provided both direction and encouragement at all stages of the study. Prof. J. R. Borsting has provided valuable advice concerning the statistical analysis of the experimental data.

Part II - Essentiality and Inventory Models

Non-Military.

The literature of inventory theory indicates that, first, the problem of essentiality ranking does exist for the non-military inventory manager and second, that no method other than the exercise of judgement by management has been devised to provide this ranking.

Many mathematical models exist for the "optimization" of inventory management decisions. In every case studied, the model provides optimal inventory decisions as to stock levels and reorder quantities for a single, specific item. Since, in practice, virtually all inventory managers are required to maintain stocks of many items, use of one such inventory model requires independent computations under the model for each of the items carried in inventory. The only factor which connects decision making for one item with that for another is the possible existance of some overall budget for the procurement and holding of stock. Where such a budget ceiling exists in a situation characterized by demand and delivery lead time uncertainty, the need for an essentiality ranking of the items of inventory is manifest. Such is the case in both military

and non-military economy.

The more sophisticated of the mathematical models have in common a function called variously a penalty function, depletion cost function, stockout cost factor or shortage penalty. The purpose of this function is to include in the computations under the model a penalty, expressed in dollars usually, for expected unsatisfied demand due to inventory shortages, based on expected demand and expected delivery lead time.

Two fundamental types of non-military application exist: Maintenance of inventory against future sales and maintenance of inventory against future production line needs.

In the first case (stocks of merchandise for sale) the shortage function should penalize 1) for the dollar loss due to missing sales and 2) for the loss of customer "good will." The expected dollar cost of missed sales is relatively easy to compute from initial stock levels, expected demand and expected delivery lead time. Loss of "good will", however, requires some kind of monetary evaluation of the degree to which a lost sale or late delivery will influence a customer to transfer some of his subsequent business to competitors. [5-p.72]

Although the identification of some items of retail merchandise as "staple" items which must be carried for the customer in order to obtain his business in other merchandise is traditional, the authors of this paper were unable to discover evidence of the use of any mathematical model in non-military practice wherein this evaluation has been made, converted to monetary terms and included as a parameter of the model.

In the second case (stocks of production materials), the shortage function should penalize according to 1) the degree of essentiality of the particular part or material to the production process, 2) the availability of substitutes, and 3) whether emergency suppliers can fill temporary needs. Ultimately, the penalty should depend on the additional cost of special procurement or production operations and on customer delivery penalties if the shipment is delayed by lack of raw materials. [5-p. 320] This case is readily translateable into the military application, with the substitution of "military mission" for "Production Process", but here, again, no evidence was uncovered that the issue has been resolved into

quantitative mathematical terms for inclusion as a parameter in a mathematical inventory model.

Indeed, the literature of the subject assumes these penalty parameters as "given" by higher level management to the inventory manager. "We assume the penalty function as given. The organization - whether commercial or non-commercial - has a general idea of the value it would attach to the damage that would be caused by the nonavailability of an item; it knows the cost and the poorer performance of emergency substitutes. The penalty for depleted stocks may be very high: 'A horse, a horse, my kingdom for a horse,' cried defeated Richard III." [5]

In the mathematical construction of inventory models, the essentiality ranking of an item (relative to other items) is usually expressed as a constant multiplier of some factor of the penalty function, and may serve to do any of the following:

1) It may stand as a separate factor of the penalty function to be imposed as a simple, constant penalty whenever demand exceeds stock;

2) It may multiply some sub-function which expresses the difference between stock and de-

mand, and which thereby varies with the number of units of unsatisfied demand;

3) It may multiply some sub-function which varies with the time duration of shortage; or

4) It may serve in some combination of the above roles.

One typical example [6-p. 19] will suffice to show how extant mathematical models provide for the inclusion of an essentiality factor (albeit unused). Arrow, Harris and Marshack have developed an inventory model containing the following simple shortage penalty function π :

$$\pi = \begin{cases} A + B(X-Z) & \text{IF } X > Z \\ \emptyset & \text{Otherwise} \end{cases}$$

Where X represents demand for a given inventory period;

Z represents stock on hand during the period;

A represents a constant item essentiality penalty factor which is applied when $X > Z$;

B represents an essentiality constant which multiplies a penalty factor varying with the number of units of unsatisfied demand.

Typically, Arrow, Harris and Marshack do not provide any method whereby A and B can be computed for each item of inventory, but assume

them to be "given" as stated in the quotation on Page 9.

Military.

"When an 'out of stock' condition arises for some military item, the problem is quite different from that of the private entrepreneur. For example, if a resident of New York City goes into a department store and finds that the store is out of stock of the article he desires, his demand probably can be satisfied in some other store. If such is the case, very little harm has been done. The first store has probably lost some profits and some good will. A store run by a rational entrepreneur should not carry stocks large enough so that a 'never-out' condition prevails. If it does have sufficient stocks of goods to insure completely against their running out, the stock levels would be far above the optimum level and the carrying charges would exceed the costs of depletion for the marginal unit. The military situation is conceptually similar to that of the private entrepreneur, but the costs of depletion, aside from the greater difficulties of measurement, may be of a much greater magnitude than is at all conceivable in private

business. If important items of equipment are not available when needed, the fate of the nation may be at stake." [7]

In the view of the authors of this paper, the most marked difference between military and non-military experience with the problem of essentiality ranking of inventory items has been the willingness of the military (especially the Navy) to come to grips with the problem and actually to provide means by which essentiality ranking of items are determined and inserted into mathematical inventory models.

Efforts within the military establishment to accomplish essentiality ranking of inventory items fall into three categories which are listed here in the chronological order in which they have made their appearance.

1) Ranking based on studies performed at supply-demand control points and Navy Department Bureaus by technical experts in the fields of inventory control, material identification or allowance list preparation.

2) Ranking based on questionnaires answered by maintenance technicians or operating personnel.

3) Formula ranking, backed by rationale,

based on readily identifiable characteristics of a specific item such as its price, demand rate, weight and cubic dimensions.

Category I - Ranking by Experts in High Supply Echelons

Presentation.

In 19[illegible], the U. S. Navy Bureau of Supplies and Accounts directed that all Naval Supply Managers classify each item under their control into one of the following ten categories [C-para 21106]:

A - Field activity controlled (items not to be subject to central or regional inventory management)

C - Carrying point controlled (items to be subject to regional but not central inventory management)

F - Fast items (with a high demand rate history)

L - Local stock (procured by local activity for local use)

M - Medium items (with medium or moderate demand rate history)

P - Perishable items

* I - Insurance items (essential items to the maintenance of in-service equip-

ment with unpredictable demand, long lead time or difficult procurement channels.)

S - Slow items (with low demand rate history)

T - Terminal items (to be used up and not replaced)

* X - Special program items (necessary to and controlled by the managers of special programs)

It can be seen that the fractionation program was not fundamentally an essentiality ranking program. Its purpose was to divide Navy-wide inventory into categories each of which is subject to different inventory management rules. Furthermore, items within a specific category were not ranked among themselves. In the cases of categories R and X, however, technical experts at each supply demand control point and in the bureaus (in the case of bureau controlled material) were required to decide whether an item was essential to the operation of some in-service equipment or to some special project. This decision and its resultant segregation of the items so categorized represented possibly the earliest large-scale essentiality classification to be

performed in military inventory management, and is still in Navy-wide use.

When an item is classified R or X, a decision is made as to an adequate "buffer stock" for total protection against stockout. This stock quantity is then added to the stock level dictated by the mathematical model.

We face, here, one of the serious problems which pervades the whole ranking issue. When an item has more than one application, what shall its fraction code be? Fortunately, only rarely do R coded insurance items and X coded special project items have applications other than those which qualify as R or X. Generally, when such are encountered, the classification causing closer control or higher stock levels is assigned. However, as we extend the concept in the direction of essentiality ranking of all items of a supply system, embracing countless items with multiple applications, the problem becomes more intense. Again, the general solution seems to be the assignment of rank corresponding to the most essential application, a plausible course of action but one which fails to consider or reflect any application other than the "highest".

Aviation Supply Office.

Before a new aeronautical equipment, such as a new aircraft engine, is placed into use, a formal provisioning procedure is followed which comprises an item-by-item technical supply determination of the quantities of supply items required to support the equipment during its expected period ef service. Included in this process is the assignment to each item to be procured of a source code very similar in nature to the fractien codes above, but more detailed and comprehensive. Several of these source codes require determination of the essentiality of the item to the operation of the equipment. Again, no ranking is done within source codes.

The principle innevatien supplied by this provisioning procedure is the cenvening of provisioning conferences attended by representatives of ASO, the Bureau ef Weapons, the Fleets, the Air Training Command, overhaul and repair facilities, equipment contractors and repair parts vendors. Basically, the same essentiality decisions are made as in the case of fractionation, but with a broader array of technical talent to do the job. Here, as before, no

essentiality decisions are made for items with predictable demand and lead time and with relatively simple procurement channels. [[illegible]]

Ships Parts Control Center and Ordnance Supply Office.

SPCC and OSO have carried the essentiality concept to the point of essentiality ranking of each item of ships machinery repair parts and ordnance repair parts respectively. Furthermore, in both supply demand control points, the ranking of each item is expressed as a number which is included as a parameter in the inventory control model used for the item.

At SPCC, item essentiality rating is based on 1) the extent to which the want of a part will reduce the effectiveness of the weapon in which it is applied, and 2) the cost of the weapon and the number of years through which its cost is to be amortized. Determination of 1) above is performed by technical experts at SPCC. Cost and amortization data are provided by the Bureau of Ships. The result is assignment of each item of ships machinery repair parts into one of three essentiality categories: high, medium or low, with appropriate

values given to the essentiality parameter in the inventory model penalty function. [10]

Three difficulties are encountered: First (and this difficulty is common to all methods in this category), the technical personnel at a supply demand control point are far removed from the scene of equipment use. Their estimate of the extent to which a weapon is ineffective for lack of a part may differ widely from experience. Second, the problem of multiple application is present in an intensified form. Finally, the cost of a weapon may not be a reliable index of its military worth.

At OSO, the assignment to each item of inventory of an essentiality factor ranging between Ø and 1 is performed by the same type of technical personnel as at SPCC. This factor is based on 1) the degree of ineffectiveness of an ordnance equipment caused by want of the part and 2) the extent to which the loss in effectiveness can be compensated by substitution or local part manufacture. This system is subject to the first two of the difficulties recognized for the SPCC method. Additionally, no cognizance is taken of the relative military importance of different ordnance equip-

ments to the effectiveness of the military unit (e. g. Ship). [11]

Category 2 - Ranking by Experienced Maintenance and Operating Personnel

TIRU Project.

Perhaps the most extensive single project yet undertaken in the field of essentiality ranking is the Logistic Research Project of George Washington University wherein every item of repair parts for a single, modern submarine (USS TIRU) was assigned an essentiality ranking through questionnaires prepared by maintenance and operating personnel. The purpose of the project was to aid in the preparation of onboard repair parts allowance lists for all submarines of TIRU'S Class.

Each repair parts item received an essentiality code composed of a number (1 thru 4) and a letter (A, B or C) where the number reflects the military worth of the equipment affected by the part failure and the letter reflects the ability of ships force to compensate for the failure without depending upon an onboard spare.

The numbers, called mission effect codes, were obtained by providing a team of nine

experienced submarine officers (former commanding and executive officers of submarines) with the design specifications of every article of equipment installed in TIRU. These officers completed a questionnaire for each equipment, dividing TIRU'S equipment into four categories:

Code 1 - Termination of patrol action. Failure of the equipment would cause the ship to break off the patrol and immediately return to port for repairs.

Code 2 - High Risk. Failure of the equipment would introduce a calculated risk into the accomplishment of the mission, the risk being restrictive in terms of the operational capability of the ship. Depending on the type of equipment which has failed, limitations such as choice of areas of operation, selection of targets, reduced defense capability, etc., might apply. The ship. however, would stay on station.

Code 3 - Moderate risk. Failure of the equipment imposes less serious

restrictions on the accomplishment of the mission and wherein the component failure can often be compensated for (e. g. by substitution of manual for mechanican operation of the equipment).

Code 4 - Negligible effect. Failure of the equipment imposes no restrictions on the accomplishment of the mission.

The hypothetical mission for which these evaluations were made was a sixty-day wartime patrol, submerged eighteen hours a day, normal snorkelling, and complete isolation from supply or maintenance support. [12]

Coincidental with the assignment of the mission effect codes above, a team of senior petty officers and shipyard repair personnel were employed in determining the maintenance potential code (letter) portion of the essentiality rating.

Team members were provided with a list of parts contained in each of the equipments installed in TIRU, along with data on the facilities for manufacture and hand tools available on board. Information on the availability of

bulk materials was also supplied. Thus armed, the team divided all items of repair parts into three categories:

Code A - No possibility of compensation. The faulty part must be replaced by an on-board spare before the equipment can be made operable.

Code B - Compensation possible. The faulty part can be compensated for by on-board manufacture, cannibilization of stand-by equipment, or substitution.

Code C - Not required. Equipment can operate without replacement or compensation.

As is seen, an item classified 1A is of the highest military essentiality; a 4C item is of the lowest.

This system has proved to be satisfactory insofar as it provides guidelines for the preparation of allowance list quantities of on-board spares for a specific class of ship. The extension of the method to system-wide Navy stocks does not seem likely for reasons of expense, the problem of multiple application, and a further problem in that an article of equip-

ment may be of the highest military worth to one class of ship, and merely stand-by equipment on board another.

Polaris Essentiality Project. [13]

The Bureau of Supplies and Accounts, The George Washington University and the Office of Naval Research are engaged at present in a project to provide essentiality ranking for all repair parts items required for the Polaris Fleet Ballistic Missile Weapons System. This project is designed along the same lines as the TIRU project above, expanded to provide a more comprehensive set of essentiality values required by the increased technological complexity and military urgency of the Fleet Ballistic Missile Weapons System. Such factors as equipment redundancy and the availability of emergency systems, not taken into account in the TIRU study, are specifically examined in the essentiality program for the Polaris System. Further, the unique features of the weapon system itself requires an essentiality concept which permits judgement to be made on whether part failures affect the total capability for missile launching, or are limited to such factors as the accuracy, reliability, rate of fire,

etc., of the launching capability.

Here again, the product, however worth while, has application limited to allowance list preparation for a specific weapon system.

<u>Flyaway Kit (USAF)</u> [14]

The authors could find but a single example of the assignment of essentiality factors to repair parts by a military organization outside the U. S. Navy. The problem concerned the development of a Flyaway Kit[1] for the F-86H Aircraft in use in the U. S. Air Force.

The method was a forerunner of the TIRU project. It included the assignment of a team of maintenance personnel to the task of questionnaire completion. Two differences from the TIRU method may be noted: 1) The probability of failure was estimated for each item and included as a factor in determining essentiality; 2) The essentiality of an item was made to vary inversely with its weight.

This program was successful, in that it has continued in use, but is subject to the same limitations of application as the TIRU and Polaris Essentiality Programs.

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[1] A Flyaway Kit is a mobile package of spare parts which accompanies an aircraft squadron when it deploys to an advanced base.

Category III - Formula Ranking

A simple, easily obtained index of relative military essentiality has long been sought. Is there not some characteristic or combination of characteristics of an item which are related to its military essentiality and which are readily obtained from catalogs or stock cards?

One of the first such indices to be discussed was proposed:

$$\text{Essentiality} = \frac{\text{Item Unit Cost}}{\text{Item Unit Size}}$$

The rationale which supported this proposal is as follows: 1) The Navy gets what it pays for. Cost varies with value. High cost items must be valuable, thus possessing a high relative essentiality. 2) The larger an item is, the less likely it is to fail. Large items include hull fittings, anchors, turrets.. They don't break... and anyway, they are too big to carry in stock aboard ships. Large items are more easily fabricated from raw materials on board, and if too big, probably require yard or tender overhaul to accomplish the replacement.

There is a large body of technical opinion which supports the general truth of this reasoning. We have seen a case in which item weight

was included (vice cube) in an essentiality rating system above (The Flyaway Kit).

<u>Electronics Supply Office - Stanford Research Institute.</u> [4 - p. 13]

In use at the present time at ESO is a model for system-wide management of electronic repair parts formulated by SRI. This model contains, as a parameter of its penalty function, an essentiality factor (called an item balance factor) as follows:

$$E = \frac{C}{\sqrt[4]{CD}}$$

In which C is the unit cost of the item and D is its weekly demand rate.

The unit cost in the numerator of the fraction is rationalized as in 1) above. The presence of a function of demand in the denominator can be justified by reasoning that high demand items are the "staple" items of Naval merchandise, such as brooms, paint brushes and wiping rags. On the other hand, Naval equipment is designed so that the essential parts are reliable - not subject to frequent failure. Indeed, the rigorous series of tests to which naval equipment is subjected is designed to establish, among other facts, the reliability

or durability of essential parts. This reasoning gives intuitive support to an inverse relationship between demand rate and essentiality.

The justification of the fourth root of CD as the specific function of demand to be used comes from simulation and actual experience. This function has provided a rationalized item balance factor of the right order of magnitude to hold ESO's inventory decisions within budget limitations, with an acceptable stock-out record for known critical materials.

The rationale underlying this formula is sufficiently acceptable for use by ESO, but no one connected with the formulation of this model, either at ESO or at SRI, believes it to be the optimum solution to the problem. "Until a more direct method for determining an item's relative importance in the supply system is devised, some such approach as that described above will have to be used to determine the value of this factor..." [4 - p. 14]

Another item characteristic which can be obtained relatively easily is the pattern of priority assignments to requisitions for the item by in-service users. Details as to possible means of obtaining and using this information to

provide an essentiality ranking of inventory items is the subject of the authors' proposal in Part III of this paper.

Part III - A Proposal For Computing Military Essentiality

The regulations of the Navy's Bureau of Supplies and Accounts require the assignment of a priority to every requisition for material by Naval users. This priority reflects both the military importance of the user's current mission and the urgency of the need for the specific material. The authors contend that a reliable index of the military essentiality of an item can be obtained by providing some statistic related to the priorities assigned to past requisitions for that item.

It is argued that items of high military essentiality are requisitioned with higher priority, on the average, than items of low military essentiality.

It is further maintained that the priority history of an item is 1) retrievable at relatively low cost from permanent records and 2) subject to low cost current collection as a part of the item transaction reporting system now in use by all supply-demand control points.

The priority system in effect in the U.S. Navy is described in detail in the exerpts from The Bureau of Supplies and Accounts Manual in-

cluded as Appendix 1. A summary of its most important features follows: [8-para 3302[illegible]-[illegible]]

1. All requests for Naval material will be assigned a <u>numerical</u> priority designator which will reflect:

   A. The <u>relative</u> <u>military</u> <u>importance</u> <u>of</u> <u>the</u> <u>requester</u>, as indicated by an assigned "Mission Category";

   B. The <u>relative</u> <u>military</u> <u>essentiality</u> of the intended <u>use</u> of the requested material, as indicated by an "end use definition code."

2. The numerical priority designator expresses the <u>relationship</u> between mission category and the applicable end use definition code, and ranges, with diminishing importance, from number 1 through 37.

3. A Naval unit is assigned one of five mission categories by higher authority:[1]

   A. <u>Mission</u> <u>Category</u> <u>1</u>: For units engaged on missions of overriding

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[1] For details as to command levels authorized to assign mission categories to subordinate units, see Appendix, Para 33Ø26-6B(2).

importance to the national defense;

B. Mission Category 2: For combatant units and units furnishing direct support to combatant units that comprise primary offensive and defensive forces, whose missions are of vital importance and directly affect national security;

C. Mission Category 3:

(1) For active fleet units which supplement or indirectly support the primary offensive and defensive forces in Mission category 2;

(2) For activities providing direct industrial or logistic support to active fleet forces;

(3) For combatant and support forces otherwise assigned mission category 4 or 5 but preparing to deploy on a tactical or strategic mis-

sion assignment within 30 days;

D. Mission Category 4:

(1) For training units and units engaged in scheduled training operations in preparation for deployment on a tactical or strategic assignment more than 30 days in the future;

(2) For units of the active fleet force inside continental United States and the Pearl Harbor area assigned scheduled overhaul, upkeep or repair;

(3) For activities providing industrial or emergency logistic support to active fleet forces;

E. Mission Category 5: For all other units and activities, active and reserve.

4. Separate tables of end use codes are provided for each of the following types of Naval unit:

A. Ships

B. Aviation units

C. Shipyards, ship repair facilities and submarine bases

D. Aircraft and missile industrial activities

E. Industrial activities not otherwise provided for

F. Research and development activities

G. Mobile construction battalions

H. Units not otherwise provided for

An abbreviated version of the end use code table for ships is provided for illustration:[1]

End Use Code	End Use Definitions
A	Material for emergency repairs required to make the ship seaworthy or otherwise capable of performing assigned mission.

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[1] For fuller detail as to end use codes for ships and for tables applicable to other unit types, see Appendix, para 33026-6E.

End Use Code	End Use Definitions
B	Material for emergency repairs without which the ship can operate temporarily as an effective unit.
C	Material for emergency repairs not contributing to operational effectiveness or safety of the ship. Material immediately required for emergency deployment.
D	Material required 1) in preparation for deployment, 2) during deployment, to maintain fleet stock levels, or 3) for maintenance of specific equipments.
E	Material required for initial outfitting and filling of

End Use Code	End Use Definitions
E (Con't)	allowance.
F	Routine requirements not otherwise provided for.
X	Medical or disaster supplies required immediately for prolonging life (lifesaving).

5. A numerical priority designator is assigned to a requisition for material by entering the table following (Table 1) with the mission category assigned to the unit and the end use code deemed applicable by appropriate unit personnel.[1]

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[1] For details as to specific unit personnel authorized to assign a given range of end use codes, see Appendix, para 33Ø26-6B(1).

END USE

(PARTS ARE REQUIRED FOR

MISSION CATEGORY	A: EMERGENCY-SEAWORTHINESS OR CAPABILITIES AFFECTING MISSION	X: EMERGENCY - LIFESAVING	B: EMERGENCY - UNIT TEMPORARILY EFFECTIVE	C: EMERGENCY-UNIT EFFECTIVE; EMERGENCY DEPLOYMENT
1 OVERRIDING IMPORTANCE TO NATIONAL DEFENSE	1	3	5	11
2 COMBATANT UNITS & DIRECT SUPPORT UNITS - PRIMARY OFFENSE & DEFENSE	2	3	8	12
3 INDIRECT SUPPORT; LOGISTIC SUPPORT; IMMINENT DEPLOYMENT.	4	3	9	13
4 TRAINING; FUTURE DEPLOYMENT; OVERHAUL	6	3	10	15
5 ALL OTHERS	7	3	14	16

TAB

MISSION CATEGORY - END USE CONVERSI

CODE

REPAIR OR REPLACEMENT FOR -)

FUTURE DEPLOYMENT; FLEET STOCK LEVELS; SPECIFIC MAINTENANCE	INITIAL OUTFITTING; FILLING OF ALLOWANCE	ROUTINE NOT OTHERWISE PROVIDED FOR	ROUTINE REPLENISHMENT (OTHER THAN OPERATIONAL FLEET UNITS	RESERVE FLEET AND RESERVES
D	E	F	G	H
17	20	22	30	37
18	21	23	31	37
19	24	25	32	37
26	28	33	35	37
27	29	34	36	37

LE 1

ON TABLE WITH PRIORITY DESIGNATORS

6. Priority designators, assigned as described above, are designed to provide a means for supply and transportation activities to process requests and shipments in accordance with military importance and urgency of need. The system is intended to determine material issue policies and efficient employment of transportation and communication capabilities.

7. To maintain the integrity of the priority system, the quantity of material requested is limited to that amount necessary to satisfy the requirement that initiated the request.

8. Fleet and overseas shore activity requests are reviewed by appropriate fleet commanders to preclude abuse of the priority system. Periodically, supply activities are requested by competent authority to furnish statistical data on priority assignments to incoming requisitions. Administrative inspections of unit retained requisition files are directed to determine whether or not priority designators are being assigned properly.

It is proposed that each supply-demand control point of the Navy augment its transaction reporting system so that the priority assigned to the request document giving rise to each item transaction shall accompany the present transaction data on all stock status reports. Since the priority of the request document is "mark sensed" by stock control personnel at all reporting activities onto the EDP transaction card, which, in turn, provides the transaction data for stock status reports, it is contended that this procedure requires only the addition of a new column to the present stock status report format.

A continuous record of numerical priority designators assigned to the most recent 100 (for example) requests for each item can be accumulated by item, and stored as accumulated in the memory of each SDCP's digital computer.

Periodically (quarterly, for example), the arithmetic mean of the most recent 100 numerical priority designators can be calculated for each item by the computer to serve as a relative index of military essentiality.

For inactive items for which more than, say, 10 but less than 100 transactions have

been reported, the arithmetic mean of all numerical priority designators reported to date can serve as the essentiality index.

For inactive items with less than 1Ø transactions reported, some other means can be employed for the estimation and assignment of an essentiality index, perhaps one of the methods described in Part II of this paper.

The upper limit of 1ØØ transactions and the lower limit of 1Ø transactions have been arbitrarily chosen for the sake of example, and are properly established by stock review system considerations at each SDCP, as is the periodicity. Indeed, at those SDCPS practicing continuous stock review, this procedure would necessarily also be continuous.

Furthermore, although the parameter studied in this paper is the mean and the estimator used is the sample mean, other parameters could be studied and, for each parameter, any of several estimators could be employed. A statistic which reflects the variance of the recorded priorities appeals to the intuition, since two items could experience the same mean numerical priority history, one with large variance, the other small. It would seem that the item

experiencing the larger numerical priority variance should be assigned a higher essentiality index, since the larger variance reflects a spread of priority assignments into the high priority categories. Alternatively, variability might properly be accounted for by using not the arithmetic mean priority but some function of the nth percentile (e.g. percent at higher priority).

Assuming the arithmetic mean to be an acceptable statistic, the periodic computation for each item would then undergo transformation to provide a number of the appropriate order of magnitude and proper units for inclusion as a parameter of the penalty function in the mathematical inventory model in use at the SDCP. It is reasonable to expect that the transformation used would retain the relative ranking of items produced by the arithmetic mean computations.

The authors believe that this entire proposal can be put into effect without the addition of personnel at any SDCP or reporting activity, using existing EDPM procedures, reporting forms and computer capacity with only minor modification. It is further believed that the priority system, by its definition, operation and regulation, represents a recorded history of Navy-wide evaluation of the military essentiality of a given item, and is

thereby superior (at least by its directness) to any essentiality evaluation system in use at the present time in system-wide supply management.

In order to investigate the facility with which the proposal can be employed, as well as to examine the extent to which rankings produced by the proposal agree with rankings produced by other methods, a limited experiment was conducted at the Naval Supply Center Oakland concerning electronic tubes. This experiment is reported in Part IV of this paper.

PART IV

TESTING THE PROPOSAL - A LIMITED EXPERIMENT

1. Abstract

A test of the proposal was conducted in two stages. First, various currently used scales applicable to military items were examined. The purpose of the examinations was to justify consideration of these scales as related to the concept of "military essentiality."

Second, a limited experiment was conducted in order to determine whether any discernible (significant) correspondence existed between an item's military essentiality as asserted by the Stanford Research Institute's E (see Part II) and military essentiality as evidenced by the item's priority history as proposed in Part III preceding.

The methods of M. G. Kendall [15] were used to make a statistical comparison of the ranking of 23 electron tubes by their average priorities with their rankings by;

1) Item Balance Factor (SRI E)
2) Item Cost (SRI c)
3) Item Dollar Velocity (SRI cD)
4) Predicted Weekly Demand (SRI D)
5) AKS Demand History (AKS LOAD LIST QUANTITY)

The results of these comparisons indicate that:

1) The military essentiality ranking of items by their average (mean) priority is directly related to their ranking by the SRI E values.

2) the military essentiality ranking of items by their average (mean) priority is meaningfully related to some of the other determinable item characteristics, the evidence being strongest in the cases involving demand (comparisons 4) and 5) preceding).

3) that a more exacting experiment is warranted in order to verify the results of the limited experiment, and

4) that the resulting more conclusive rankings should be used to investigate the relationships of other determinable item characteristics to priority derived military essentiality.

2. The Experiment.

A. Conception of the Experiment

As set forth in Part III preceding, it had been observed that the Navy's priority system entailed the repeated direct evaluation of the mission and end-use effects of shortages of individual repair parts. The system also involved implications of the effects of cannibalization, substitutability, local fabrication and stock storage capacity. It was further observed that this machinery, whatever its other uses, bore the characteristics of a current and continuous field survey of military essentiality. In this the process was not unlike the survey methods being employed by the Naval Logistics Research Project team of George Washington University for establishing the spare parts allowances of TIRU class submarines. No more cogent an approach to the determination of military essentiality than that of the George Washington University group has been disclosed by research.

The foregoing observations suggested the possibility of approximating an empirical verification of that conception underlying both of these approaches to military essentiality. By ranking the same inventory items under both the George Washington University questionnaire method and a method

based on priority characteristics, the two rankings could be compared for statistical agreement. However, the specialized purpose (allowance lists) and limiting conditions (TIRU class submarines during war patrol) of the George Washington University determinations provided only a discouraging prospect for meaningful comparisons with essentialities indicated by the urgency of the present procurement needs of a wide variety of end users. However, an attempt was made to correlate the George Washington University values with not only the SRI E values but also with those values of the proposed scheme. In every such comparison, no significant evidence of a correlation was noted.

For these reasons attention was returned to the Stanford Research Institute inventory control model, the study of which occasioned these present considerations. In it the "Item Balance Factor", E, played the role of a military essentiality ranking for each inventory item to which the model was to be applied. The lack of intuitive appeal underwriting the SRI E had caused its name to be changed in the final analysis from "Essentiality", under which name and conception it took its place as a term in the derived form of the model, to "Item Balance Factor". It will be necessary to look at the history and function of E in some

detail in the paragraphs which follow in order to estimate the confidence it may be accorded as a "true" index of item military essentiality. In early 1959, the SRI mathematical inventory model was placed in use for a pilot class of items in Federal Stock Classes 5960 (tubes and tube hardware) and 5995 (wire and cable assemblies). A typical Federal Stock Number (FSN) for an item in the pilot class is NF 5960 033 6355, in which N is the Navy cognizance symbol for electronics repair parts controlled by ESO, F is the fraction code for a high demand (fast) item, 5960 indicates tubes and tube hardware, and the remaining seven digits are the catalog number of the individual item (specific tube).

The relative military essentiality E assumed for the pilot model was $E = \sqrt{C}$, based on the traditional proposition that essential items are expensive, that essentiality therefore varies directly with cost, and the belief that $\sqrt{C}$ is the function of c which would yield factors of a reasonable order of magnitude. The original suggestion of cost or value as a utility measure was made by Daniel Bernoulli, and the classic variation $\sqrt{C}$ was suggested to him in a letter from Gabriel Cramer in 1731.

The results of the early applications of the model yielded, for a great many items, reorder levels of less than a leadtime. Reorder levels of less that a leadtime result in stockouts, a condition acceptable in a large supply system for a small number of relatively unessential items, but not to the degree experienced in these early results. SRI and ESO personnel were able to identify five possible causes of the unacceptable low reorder levels:

1. Insufficient operating funds
2. Too little allowance for order cancellations and reductions of buy quantities where demand failed to develop as expected.
3. An assumption that amounts "back ordered" (requisitioned by Naval users and awaiting stock deliveries) never exceed the order quantity.
4. Holding cost assumptions.
5. The assumption that $E = \sqrt{C}$.

The effects which the above five points had on reorder levels and order quantities were studied by examining the behavior of the rules resulting from changing various combinati ns of the conditions of and assumptions described in these points.

Six representative synthetic items were developed to simulate the actual population of the pilot

class of items. The six items were chosen by dividing the entire pilot class of items into six dollar velocity subclasses: [4]

CLASS	WEEKLY DOLLAR VELOCITY (cD) RANGE ($/wk)	NUMBER OF ITEMS IN RANGE
1	cD ≥ $3,840.00	22
2	384.00 ≤ cD < 3,840.00	198
3	38.40 ≤ cD < 384.00	540
4	3.84 ≤ cD < 38.40	890
5	.38 ≤ cD < 3.84	830
6	.04 ≤ cD < .38	660

The median dollar velocity value and unit price in each of the above dollar velocity ranges were used for the six synthetic items, giving the results shown in the following table:

ITEM NUMBER	WEEKLY DOLLAR VELOCITY CD ($/wk)	UNIT PRICE (c)	WEEKLY EXPECTED DEMAND D=cD/c
1	6,500.0	500	13.0
2	800.0	20	40.0
3	96.0	8	12.0
4	12.0	5	2.4
5	1.0	3	0.333
6	.2	2	0.1

For all six items, representative values of parameters of the model not involving the five factors to be studied were chosen, such as leadtime, order cost, and holding cost.

By means of this synthetic sample it was possible to reconstruct the approximate behavior of the model with respect to reorder level and order quantity when changes were made to the five factors under study.

It was found that, of all the factors varied, the model was most responsive to variation of the assumption of the value of E, relative military essentiality.

It was readily recognized at this point that the "actual relative military essentiality of the various items was not being emphasized as a criterion for choosing the item essentiality factor, E. Instead, the "balance" of reorder levels among items in the system had become the principal criterion, thus giving rise to a new name for E: Item Balance Factor. The criterion established for E was: no matter how it is determined or assigned, it should yield an insignificant number of items with reorder levels less than a leadtime.

$E = \frac{c + \sqrt{c}}{2}$ was the first alternative to $\sqrt{c}$ studied. Whereas $E = \sqrt{c}$ had

failed to provide adequate reorder level protection particularly among the high velocity items, $E = \frac{C + \sqrt{C}}{2}$ failed in the same manner for low dollar velocity items. Following the failure of these first two assumptions, a solution was sought by reviewing several essentiality rationales which had been investigated prior to the beginning of the pilot study. One argument said that all items are equally essential -- whether it be a $10,000 special purpose electron tube or a 10-cent resistor. Failure of either could incapacitate a radar and imperil a mission. Consequently, the assumption $E = 1$ was investigated, but failed even more markedly than $E = \sqrt{C}$ to provide adequate reorder level protection among high dollar velocity items. Another possibility was the assumption that every dollar's worth of an item, rather than the item itself, is equally essential. If this were not so, the argument goes, one would not be willing to pay the price for the item. Accordingly, the assumption $E = C$ was investigated, and was found to provide the poorest reorder level protection of any assumption studied among the low and medium dollar velocity items.

Two combinations of those last two assumptions were studied: $E = C+10$ and $E = C+50$, revealing that

variations in the value of the additive constant could change the dollar velocity range in which the model failed, but could not eliminate failure.

The rationale underlying the assumption E = C was considered to be the strongest of all those studied, hence, it was decided to determine effect of introducing an additional factor into the E = C assumption which would increase the E of the low dollar velocity items, the area in which this assumption had failed. This could be accomplished by dividing cost by some power of dollar velocity. The question then was: what is the appropriate power of cD?

The assumption: $E = \frac{C}{(cD)^{1/2}}$ was tried, and did indeed raise reorder level protection for low dollar velocity items without sacrifice of protection for high dollar velocity items. The increase in reorder levels for low dollar velocity items was, in fact, too great, resulting in unacceptably high inventories of these items.

At last, $E = \frac{c}{(cD)^{1/4}}$ was investigated. This assumption provided the same general characteristics in the low velocity area, and without the excesses (relatively speaking) of $E = \frac{c}{(cD)^{1/2}}$.

The general conclusion which has been drawn from the aforementioned investigations is a basic

assumption that a dollar's worth of any item is equally essential (E = c), modified by a factor $1/(CD)^{\frac{1}{4}}$. This assumption yields at least an interim solution to the question of a suitable item balance factor, E. The SRI staff suggests that the basic assumption E = c forms a natural point of departure for a more fundamental determination of this important parameter. Inherent in the proposal of Part III is the suggestion that the Navy's priority system, or some specially designed parallel to it, represents a point of departure even more fundamental in character.

In summary, despite the weak theoretical appeal of the final SRI military essentiality factor, E, the values it attaches to inventory items enable the model to generate quantities known to be in agreement with existing inventory control experience. The approach used is not without precedent and has achieved many remarkable successes in the physical sciences.

For the foregoing reasons, coupled with the generality and current character of the inputs to the E determinations, there seemed to be promise of a fruitful result from a comparison of the SRI military essentiality rankings with rankings based on priority history. If these rankings did not

agree, little would have been learned about the validity of either system. If the two systems yielded significantly similar rankings, then both would appear to approximate the same property of the items thus compared. From such a result one might hope for;

1) a better understanding of the nature of military essentiality,
2) potential improvements in the applications of this concept, and ultimately
3) realistic, economical and sensitive military essentiality rankings.

B. The Sample Design

Having conceived an experiment in military essentiality as outlined in the preceding paragraphs, it became necessary;

1) to ascertain the availability (recoverability) of data,
2) to define that subset of all requisitions which would be pertinent to or interpretable as expressions of military essentiality and,
3) to devise and adopt a scheme for selecting which of the 3130 pilot project items of Federal Stock Classes 5960 (electron tubes) and 5995 (cables and cabling) would be compared.

The carrying out of these tasks and the nature of the resulting sampling are described in some de-

tail. The description is provided to enable the reader to evaluate the experiment. It will also provide an example of a data reduction problem typical of those encountered in Operations Analysis.

1. The Availability of Data.

In the last week of June, 1960, the Control Division of the Ship's Supply Depot of the Oakland Naval Supply Center was requested to select two electron tubes of the 5960 class as might be most convenient (implies high demand rate). For all expenditures to end users of these stocks they were requested to report; the quantity of these tubes in each transaction, the identity of the end-user, the priority and date of the original requisition, and the date the material was required by the originator. This research was to extend backward in time to January, 1960, on which date the existing priority system became effective.

In about ten days, the first eighty observations of the sample later numbered 17 (stock number order) and the first thirty observations of the sample later numbered 8 were received. These observations were received, as were all subsequent observations, in the form of duplicates of the original requisition documents in one of several extent forms. A review of these documents and the procedures by which they were recovered yielded

the following conclusions:

1) the records research was more difficult than anticipated and involved:

    a) a requisition-to-requisition back search through chronological stock transaction ledgers, then

    b) interpretation of codes accompanying the ledger entries so as to select end-user transactions from among stock adjustments, then

    c) recourse to document files where further end-user discriminations occurred, then

    d) removal, duplication and refile of documents.

Recourse to the original document was necessary because it alone preserved the priority notation, and it alone allowed the kinds of end user discriminations which became necessary. However, based on the man hour and cost reports which accompanied this first report, it was decided that large scale sampling by this method was feasible. It later developed that these first trial samples were anomolous and were the most easily researched of the entire experiment.

2. <u>The Sample Space of Priority Designators</u>.

From these first samplings and from subsequent samplings, it became clear that many possible end-

users would have to be eliminated from consideration (e.g..air stations, ship yards, tenders, etc.) because they requisitioned material as stock for subsequent re-issue to other end users. It was not possible in such instances to distinguish between the mission categories and end use codes of the " [illegible]" table. For these reasons and others which developed from subsequent experience, it became easier to identify culls by the priority designators they used than by the identity and exact nature of the functions of the originating command. In effect, the experimental sample space became the requisitions of the ships and aircraft squadrons of the active fleet as seen through their priority designators; this was tantamount to the elimination from the Conversion Table (Table 1) of;

Column H (reserved and reserve fleet)

Column G (end uses not pertinent to operational units)

Column K (life saving) and

Row 5 (administrative and type commanders, Military Sea Transport, Service vessels, operational commanders such as Marine Air Wings, Carrier Divisions, Air Groups, etc.)

The new sample space of priority designators thus defined appears in tabular form as in Table 2 following:

Mission Category		END USE CODE A	B	C	D	E	F
	1	1	5	11	17	20	22
	2	2	8	12	18	21	23
	3	4	9	13	19	24	25
	4	6	10	15	26	28	33

Table 2

Reduced Conversion Table Showing the Sampled Priority Designators

The restriction of sampling to the designators shown above greatly reduced the ratio of useful recorded transactions to total end user transactions. Sample number 17 decreased 30% in size and sample number 8 decreased 20%. In summary, these reductions were adopted in order to avoid cases where there was masking of the ultimate end users by intermediate suppliers who were themselves end users. Furthermore, it was desired to restrict the observations to organizations for which a full range of mission categories and end use codes were possible.

3. Initial Item Selection.

Because of its size, variety and activity characteristics, class 5960 (electron tubes) was chosen as the source of all the items to be sampled. When Stanford Research Institute examined the effects of various assumed forms for the relative military essentiality E, it did so by creating six synthetic

items which were weighted to simulate the actual population of the pilot class of items. The six items were chosen by dividing the entire pilot class of items into six dollar velocity subclasses as shown in the Table preceding. The median dollar velocity and unit price in each of these dollar velocity ranges were used to select the characteristics for the six synthetic items giving the results shown in the Table preceding. The six synthetic items thus created were used to test the effects of the various model assumptions.

It was desirable to follow the same reasoning in selecting the experimental items from stock class 5960. However to increase the number of items to be observed, the median dollar velocity and unit price of the intervals determined by the 1st, 2nd, 3rd and 4th quartiles in each dollar velocity range were used to produce 24 synthetic items instead of 6. Given the characteristics of 24 synthetic items thought to be representative collectively of the whole class under consideration, actual members of the class of electron tubes were selected which duplicated closely the characteristics of the synthetic 24. These tubes were then taken to be those whose priority history would be researched in order to test for a correspondence between the two schemes for determining military essentiality.

The actual sample items so selected and their characteristics are not presented here because the circumstances of sampling forced the abandonment of this scheme, as is recounted next.

C. Sampling.

Sampling was conducted from the end of June, 1960 until the end of February, 1961, a period of eight months, which covered the first fourteen months of existence of the new priority system described here in Part III. This sampling resulted in accumulating 9 to 33 transactions for each of 23 items in the electron tube class. The decision to accept sample sizes of as few as 9 observations was based solely on the fact that the specification of any large size would have unduly limited the range of E values being considered.

For a fourteen month sampling period (not continuous for all items) the small number of usable transactions for the sample items was surprising (average used was 23). This was accounted for by;

1) the chosen restrictions on the sample spaces,
2) the low demand characteristics of many of the selected items, and
3) the use of only one Supply Center as a data source.

The third circumstance cited above, not mentioned heretofore, requires some comment.

There are two Naval Supply Centers in the Navy supply system, NSC Oakland and NSC Norfolk. Each has, as components, several depots stocking the various categories of materials. The Ship Supply Depot at NSC, Oakland, for example, stocks cognizance H (ship's repair parts) and cognizance N (electronic repair parts) material. Each is a "distribution point" in the supply system for electronics repair parts, which means that each is an echelon of supply subordinate only to the Bureau of Supplies and Accounts and the Electronics Supply Office. In its role as a distribution point, NSC Oakland carries stock in support of designated continental and extra-continental primary stock points, such as supply depots and shipyards. The supply support of active fleet units is but a secondary activity of this NSC, along with support of secondary stock points in its immediate area (e.g. air stations) and the support of yard and district craft. The cause of many of the sampling problems encountered in this study was the fact that coastal supply depots, shipyards and supply vessels are the major sources of supply support for the active Pacific fleet. The NSC Oakland performs this which is only a secondary responsibility. However,

the Center provided a simply authorized and controlled data collection point of sufficient traffic volume, clerical resources and flexibility to be desirable for the purposes at hand.

B. First Sampling.

During July, 1960, with the personal approval and support of Rear Admiral R. J. Arnold, SC, USN (then Commanding Officer of the Oakland Supply Center) the authors, with the assistance of Lcdr. J. D. Frost, SC, USN (a student at the Stanford University Graduate School of Business) spent three weeks in a first hand search for data in accordance with the dollar velocity class scheme. Although many substitutions were made for the items originally selected as the real counterparts of the 24 synthetic inventory items, only 18 of these 24 items had recorded one or more experimentally pertinent transactions in the six months' history of the new priority system. Of these 18 (not including the initial 2 "feasibility" trials) fewer than half recorded 5 or more transactions of interest. None exceeded 24.

Rejections at the stock transaction ledger point of the research process approached 90% of all transactions encountered there. Very heavy activity in stock reallocations and other adjustments accounted for most of these rejections.

Approximately 50-75% of these remaining transactions involving a stock expenditure to end users were rejected as being non-fleet, or non-final end user issues and these were then outside the space of sample priority designators. Of these, problems of recovery from files or errors in the original documentation accounted for a further 10-20% sample size degradation.

It is reasonable to remark here that organizational problems outside the areas of procurement, inventory and issue control do not offer the same important opportunities as these areas for improving the supply system's overall effectiveness. These problems have not therefore warranted the kind of analysis, supervision and modernization effort being invested elsewhere. However, Electronic Data Processing is being applied for the more important processes and improved recoverability of data for analysis purposes will undoubtedly result as a by-product. The heavy reallocations activity is also being studied and significant reductions should be achieved soon.

In summary, because of the much slower than expected activity in many of the selected dollar velocity classes of electron tubes it was not possible in these classes to acquire samples of useful size. As a result, the dollar velocity

scheme was abandoned.

2. Second Sampling.

Because of a wide variability among items in the cause and extent of transaction rejections, it was not possible to predict which items of the inventory were more likely to yield a usable sample size. Generally, of course, fast moving items were more promising than the slow. Upon request, the Ships Supply Depot Officer-in-Charge agreed to extend additional support to this study beyond the original plan. Under the direction of Mr. T. F. Bailey, Control Division Supervisor, the clerical force of the Control Division was now to continue the research until any additional 25 electron tubes could be found for which as many as 25 usable transactions could be found. Research on each item was to terminate when 25 suitable transactions had been found. Commencing in September, 1960 and continuing until January, 1961, this goal was reached for only 6 additional items. However, a total of 17 additional useful samples were acquired. As might be expected, this group of items tended to be rather uniform in its characteristics, giving a disappointing spread of E values.

3. Third Sampling.

Since the uniformity of item characteristics in the second sampling threatened to render the

intended experiment irrelevant to the import of the range of E values, the Oakland Ship Supply Depot was requested to reopen research on all the non-zero transaction items in the first sampling which were intentionally characterized by greater variability. The purpose of this "second look" would be to make available the results of the most recent 8 months of experience in these 20 items (now numbered 1 through 20 in stock number order). This would increase the time base for them to a total of 14 months. This was done. At the same time, one month's additional research was conducted on the items of the second sampling.

4. <u>The Inventory Items of the Final Sample</u>.

At the end of February the time remaining for analysis would not permit any further enlargement of the samples, and sampling was therefore concluded.

In the end, 23 of the original 43 electron tube samples were deemed large enough to be retained. For these, records had been obtained on [illegible] transactions affecting the expenditure from Supply Center Stock of 3867 tubes valued at about $34,000. These 23 tube stocks involve Navy-wide annual expenditures of over $3,000,000.

Table 3 following shows the 23 tubes in the final sample along with some of their chosen characteristics.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
02	F	1[illegible]-7144	12.[illegible]	7[illegible]
0[illegible]	F	1[illegible]7-[illegible]133	[illegible]47.7[illegible]	33.[illegible]
0[illegible]	F	[illegible]-3915	1.[illegible]	386.[illegible]
0[illegible]	F	[illegible]-0035	.[illegible]	109.3[illegible]
0[illegible]	F	2[illegible]-0[illegible]	[illegible]	1[illegible]70.[illegible]
[illegible]	F	[illegible]2-0108	8.[illegible]	21.[illegible]
17	F	[illegible]-[illegible]528	1.[illegible]	[illegible]102.7[illegible]
20	F	16[illegible]-7[illegible]5	.[illegible]	1[illegible]0.22
2[illegible]	F	1[illegible]-0376	[illegible].10	[illegible].23
22	F	1[illegible]-[illegible]	1.3[illegible]	[illegible].17
[illegible]	F	18[illegible]-[illegible]	3.70	[illegible]
[illegible]	F	22[illegible]-0052	[illegible]	[illegible]
[illegible]	F	[illegible]-3706	11.[illegible]	[illegible]
[illegible]	F	[illegible]	[illegible].20	175.0[illegible]
[illegible]	F	2[illegible]-0163	1.00	1024.04
[illegible]	F	2[illegible]-0173	[illegible]	[illegible].7[illegible]
[illegible]	F	[illegible]-1357	.2[illegible]	[illegible]
32	F	3[illegible]-5[illegible]23	7.97	[illegible]45.95
33	F	28[illegible]-0[illegible]25	1.[illegible]	[illegible].01
34	F	355-7250	1[illegible]	[illegible]
3[illegible]	F	543-1[illegible]	.51	231.[illegible]
36	F	5[illegible]-0[illegible]	.2[illegible]	[illegible]07.[illegible]
37	F	60[illegible]-0232	13.28	[illegible]6.0[illegible]

[illegible] CONCENTRATED LOAD [illegible],

[illegible]

[illegible]

AMS LOAD LIST* (#)	ANNUAL DOLLAR VELOCITY ($)	SRI E VALUE
1005	65,264	2.77
30	433,711	36.37
699	22,346	.30
0	5,346	.29
30	1,145,161	1.32
191	9,639	2.29
1155	444,278	.14
0022	3,356	.16
40	16,794	1.22
356	63,691	.23
56	21,949	.82
181	14,732	.28
31	12,902	2.60
56	47,330	.95
850	84,450	.157
512	127,852	.400
999	185,872	.13
350	347,770	.78
173	42,838	.51
125	32,028	2.20
33	6,142	.15
227	13,208	.07
4	38,706	2.54

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3

From Federal Stock Class 5960

It is perhaps best at this point to remark on certain features of this overall sample which will become more interesting later. These features are:

1) Only tubes coded F, denoting fast moving stock, accumulated a usable number of transactions during the sampling periods. The average of the SRI E values of these retained samples is 2.40.

2) Of the 20 rejected tubes, 5 are coded F (fast, 5 are coded M (medium) and 10 are coded S (slow). The average SRI E value of the rejected sample tubes is 2[illegible].72.

The inverse relationship between E and demand was having a greater effect on the range of E values in the group of the larger samples than might be expected. It remained to be seen if such a relationship existed between average priority and demand.

5. The Data.

When all the copies of the documents of all the samplings were finally assembled, they were abstracted onto IBM punch cards for the several sortings and printings which facilitated the display and analysis of their data. The following table, Table 4, gives the data resulting from the several sampling efforts in the previously described sample space of priority designators. It

will be noted that the table does not provide for the priority designators of mission category 1 (designators 1,5,11,17,20,22). Indeed, only one designator of this category was observed, and it appears to have been used erroneously. For this reason the table omits these designators. The interpretation and treatment of this phenomenon is discussed in later sections.

[illegible] -

No. [illegible]	2	[illegible]	10	12	[illegible]
[illegible]		1/4			1/4
[illegible]	1/2	2/[illegible]	1/[illegible]	1/2	2/5
[illegible]		2/[illegible]			
[illegible]					1/[illegible]
[illegible]			2/[illegible]		
[illegible]					1/[illegible]
[illegible]				1/[illegible]	
[illegible]	1/10				
[illegible]					1/2
[illegible]		2/[illegible]			
[illegible]					1/[illegible]
[illegible]					
[illegible]				2/[illegible]	1/[illegible]
[illegible]				1/[illegible]	
[illegible]				1/[illegible]	
[illegible]					
[illegible]		2/[illegible]			
[illegible]					
[illegible]					2/[illegible]
[illegible]					2/[illegible]
[illegible]					2/[illegible]
[illegible]		1/2			
[illegible]		1/[illegible]			[illegible]
[illegible]	[illegible]	[illegible]	2/[illegible]	[illegible]/17	17/[illegible]

Table

[illegible] - [illegible] OF ALL

(# TRANSACTIONS /# UNITS)

15	18	19	21	23
		17/43	1/[illegible]	
2/2	1/1	14/12	1/1	2/3
	1/[illegible]	12/44		1/2
		3/5		
1/5	1/[illegible]	17/65		
	1/4	17/50		
1/4	3/[illegible]	23/474		1/8
1/3	[illegible]	2/8		1/3
1/15		7/23		
	3/41	8/49		
	3/55	1/2		2/4
1/6	2/24	4/51		
	1/5	3/7		
	1/2	16/55		1/2
	1/27	10/44		
		1/2	1/1	
1/7		14/68		
	1/32	11/50		1/4
2/16		7/24		
1/1		10/27		
		1/4		1/[illegible]
1/3	3/[illegible]	8/40		
1/4		3/9		
13/[illegible]	25/[illegible]	222/1[illegible]	5/[illegible]	10/[illegible]

4

[illegible]

P[illegible]IORITIES RECORDED -

[illegible]	24	25	26
[illegible]		2/3	5/5
[illegible]	3/3		
[illegible]	2/[illegible]	2/5	4/7
[illegible]		2/14	[illegible]
[illegible]	2/4		1/3
[illegible]	1/6		1/10
17	2/17	8/41	10/318
20	1/10	1/2	1/12
21			
22	1/2		1/12
23	3/[illegible]		1/1
24	1/2		2/[illegible]
25			
27	1/1	2/2	
28	2/10	2/9	4/10
29	1/3	4/25	1/3
30	2/15	3/50	2/24
32	2/7	1/3	3/[illegible]
33	1/10	1/1	2/12
34	2/3	1/2	
35			
36	2/14	2/26	
37			
Total	31/17[illegible]	31/183	32/440

Table

DATA - PRIORITIES ALL

(# TRANSACTIONS /# ITEMS)

28	33	Totals
2/2	5/21	34/102
	2/4	33/45
4/10	3/28	31/172
2/14	1/4	10/46
6/9	3/152	38/550
	1/2	22/86
20/229	9/216	83/1451
1/1		11/52
		9/41
2/16	4/43	21/176
		16/83
2/7	4/17	16/103
	2/2	9/23
3/[illegible]	1/29	26/103
2/[illegible]	4/55	29/162
	1/1	9/35
1/7	3/13	29/202
1/2	3/5	26/92
5/28	3/11	23/120
1/1		25/36
5/13		10/47
1/3	1/2	20/100
2/3	1/4	[illegible]/26
[illegible]/43[illegible]	56/[illegible]	53[illegible]/3867

4 Continued

SELECTED ITEMS AND TRANSACTIONS

D. Analysis of the Data. Reference to the table of data given herein as Table 4 reveals a striking fact. Of all of the priorities occurring, by far the most frequent was priority 19 (41/30% of the totals). Plotting histograms (priority frequency bar graphs) for each item showed that the extraordinary incidence of 19's resulted in a bi-modal (two-peaked) distribution of priority frequencies. A bi-modal distribution for the priority frequencies contradicted what one might properly expect; that is, that the priority observations for some one inventory item are a random variable distributed about and tending to cluster about some one priority which characterizes that item. Consequently, the bi-modal phenomenon provoked an inquiry into the source of the 19's observed. The investigation of the 19's revealed the following:

1) An unanticipated feature of the Navy's new priority system provided that, for any operational unit within 30 days of deployment, the end use and mission category become identically defined. (See Part III, ----Table 1). This end effect has not been coordinated of the conversion table of Table 1 , and thus only one priority resulted for all material end uses, namely 19. Whether this feature is intentional is not known. It has the effect of [illegible] all the lower priorities of mission catego-

gories 3, 4 and 5 and end uses D, E, F up to priority 19 thirty days before deployment. It is natural perhaps to procrastinate and thereby delay some replenishment efforts until shortly before deployment, but the provisions of the priority system put a premium on delay. Delay would authorize using a uniformly high priority for all requisitions. That the high incidence of 19's represented an abuse of the priority system and of proper replenishment timing was confirmed by inspectors and supervisors who were consulted.

2) A special class of radar picket ships, having a much greater than average consumption of electron tubes, was operating from the coasts of the continental United States on a "30 day out", "30 day in" schedule. In effect then, these vessels were always able to avail themselves of the advantages of the "pre-deployment mission and end use category" for all their demands --- and naturally did so.

3) A large majority of the West Coast Ships specified in 2) above were assigned San Francisco as their home port and thus made all their demands directly on the Naval Supply Center at Oakland.

In view of the facts revealed as to the source of so very many priority 19 observations, the uni-

model conception of the priority distributions was retained. The problem then became one of devising a method for properly removing an influence which obscured the underlying distribution. Several schemes were developed with statistical integrity for estimating what fraction of all 19's were not native to the underlying distribution and should therefore be removed so as to separate what amounted to two mixed distributions. However, the scheme at once most justifiable and most easily implemented was to reject all the transactions originating in the special class of vessels. This once again affirmed the definition of the sample space of originators as the regular ships and squadrons of the active fleet.

The removal of all of the requisitions of the anomalous class of ships reduced the final sample to 3[illegible]8 transactions involving 31[illegible]3 units, reductions of [illegible].6 and 1[illegible].2 percent respectively. The number of priority 19 transactions was reduced to 109 from 222, a reduction of 51 percent. These revised data are given in Table 5 .
Both the groups of data, with and without the special ships, were retained and the statistical analyses were carried out with each. By this means the correctness of the removal procedure might be estimated or, alternatively, the importance of such anomalies might be evaluated.

TRICHITES RECORDED

Sample Number	8	[illegible]	10	12	13	15
01					1/4	
02	1/2		1/1	1/2	2/5	2/2
05		1/6				
07						
08			2/12			1/5
09						
17				1/6		1/4
20	1/10					1/3
21					1/3	1/15
22						
23					1/15	
24						1/6
25				2/[illegible]	1/4	
26				1/3		
27				1/1		
29						
31		1/3				1/7
32						
33					2/24	2/16
34					2/2	1/1
35					2/22	
36		1/2				1/3
37		1/2			1/4	1/4
Totals	2/12	[illegible]	3/13	6/17	15/83	13/66

TABLE

DATA – SPECIAL SAMPLES RECEIVED – TRICHITES

(# TRANSACTIONS /# UNITS)

18	19	21	23
	5/17	1/20	
1/1	7/7	1/1	
1/6	2/14		1/2
1/300	11/42		
1/4	5/8		
3/68	22/252		1/8
2/3	2/8		1/3
	7/23		
3/41	4/41		
8/55	1/2		2/4
2/14	4/51		
1/5	3/7		
1/2	8/39		1/2
4/27	3/19		
	1/2	1/1	
	4/15		
3/10	5/32		1/4
	6/23		
	1/4		1/8
3/18	5/24		
	3/9		
34/554	100/346	3/22	8/31

5

OF ALL SELECTED ITEMS AND TRANSACTIONS

PRIORITIES RECORDED

Sample Number	[illegible]	[illegible]	[illegible]
01			5/5
02	2/3		
05	[illegible]	1/[illegible]	[illegible]/7
[illegible]		1/12	1/8
[illegible]	2/4		[illegible]/3
[illegible]	1/[illegible]		1/10
17	2/17	7/17	10/310
20	1/10	[illegible]/2	1/12
21			
22	1/2		1/12
23	[illegible]		1/1
24	1/2		2/6
25			
27	1/1		
[illegible]	2/10	2/9	4/10
[illegible]	1/3	3/21	1/2
30	[illegible]	1/12	2/24
32	2/7		3/9
33	1/10		2/12
34	2/3		
35			
[illegible]	2/24		
37			
Totals	30/17[illegible]	[illegible]/75	39/440

TABLE

DATA - SPECIAL UNITS REMOVED - PRIORITIES

(# TRANSACTIONS /# UNITS)

32	33	Totals
2/2	5/21	19/69
	2/4	21/28
4/10	3/28	19/138
2/14	1/4	5/38
6/[illegible]	8/152	32/534
	1/2	2/30
20/[illegible]	9/216	76/1205
1/1		11/52
		9/41
2/16	4/43	15/155
		16/83
2/7	4/17	[illegible]/103
	2/2	9/23
3/[illegible]	1/29	16/85
2/[illegible]	4/55	22/137
	1/1	8/31
1/7	3/13	16/[illegible]
1/2	3/5	13/[illegible]
5/28	3/11	21/124
1/1		6/7
5/13		10/47
1/3	1/2	15/[illegible]
2/2	1/4	9/2[illegible]
60/430	56/402	398/3187

5 Continued

OF ALL SELECTED ITEMS AND TRANSACTIONS

D. The Method and Results of the Analysis.

1. Final Definition of the Sample Space. It was previously noted that only one use (erroneous) of the end-use codes of mission category one (national emergencies) appeared in the sample space of priority designators heretofore defined as in Table 2. Inquiry indicated that this category is reserved primarily for war and during the period in question it was not authorized. While a general system would certainly retain these designators, it did not appear possible to assign these priority designators during any of the experimental sampling periods. Therefore these impossible outcomes were struck, as a row, from the sample space.

Thus was finally achieved a set of priority designators which each specified but one end use and mission category and which was thought to be complete for the chosen types of commands and all their possible missions. From these, proper deductions about military essentiality might be drawn. The priority designators of this set were then re-numbered in order of increasing magnitude. This last step nullified the effect of the irrelevant or discarded priority designators. Retention of the old designators would have implied varying degrees of difference between consecutive designators.

The designators thus selected and numbered are shown in Table 6 following:

Mission Category		End Use Code A	B	C	D	E	F
	2	2	5	8	11	13	14
	3	3	6	9	12	15	16
	4	4	7	10	17	18	19

Table 6

Final Sample Space of Priority Designators as Re-Numbered

2. Choice of Statistics.

The chosen problem is that of finding the relation, if any, between the SRI formula values for essentiality and the priority behavior of inventory items.

We chose to compare the rankings of common items under these two systems because

1) a preferential ordering of items is theoretically the more cogent,

2) there were insufficient grounds on which to base specific assumptions concerning the distribution of the item priorities and of E, and other item characteristics. Normal correlation depends on such assumptions.

3) the lesser sensitivity but greater generality achievable by a non-parametric rank correlation was more suitable to the nature and purpose of this limited experiment.

We chose to regard the priorities registered for some one inventory item as a random variable tending to cluster about some characteristic value, the true mean of their distribution, which is then defined to be the military essentiality number of that item.

Since the sample average is usually the best estimator of the true mean, we use an item's average priority as our estimate of its military essentiality number. Although in this limited experiment the variance of the priorities is naturally quite large, the average is still the best estimator of the true mean and is used to whatever accuracy is necessary to establish each ranking. A question remains as to whether the average priority of each inventory item is to be taken to be:

1) the average priority of all the transactions observed for that item, each transaction to have a weight 1, or

2) the average priority of all the transactions observed for that item, each transaction to have a weight equal to the number of units of

the item involved in the transaction.

Good arguments can be advanced for both approaches and therefore both approaches were used. Table _7__ following gives the average priorities calculated under both schemes with the associated estimate of the standard deviation.

Sample Number	$\overline{PR}$	s_r	$\overline{PU}$	s_u	$\overline{PR}^*$	s^*_r	$\overline{PU}^*$	s^*_u
01	14.12	3.3	13.76	3.4	[illegible]	3.2	14.78	3.3
02	12.42	3.3	12.33	3.8	11.85	2.9	12.27	3.4
05	14.12	3.5	14.75	3.1	15.62	3.3	15.26	2.0
06	14.90	4.5	16.46	2.2	17.30	1.0	17.26	1.0
08	14.37	3.5	13.41	3.7	14.01	3.0	13.45	3.7
09	12.50	[illegible]	12.42	2.5	13.53	2.6	14.60	2.6
17	15.23	[illegible]	15.40	3.0	15.32	2.1	16.02	2.6
20	12.54	4.2	11.34	5.4	12.34	2.1	14.13	4.2
21	11.44	1.1	11.05	1.1	11.44	1.1	11.05	1.1
22	13.52	[illegible]	14.18	[illegible]	15.00	3.4	14.72	3.5
23	12.44	2.1	11.17	1.7	12.44	2.1	11.17	1.7
24	15.06	3.4	13.66	3.1	15.06	3.4	13.66	3.1
25	12.22	[illegible]	11.00	2.9	12.22	[illegible]	11.00	2.9
27	13.27	2.5	14.50	3.4	13.57	3.0	14.94	3.6
28	14.22	3.1	15.12	3.4	15.01	3.3	15.69	3.4
29	15.56	[illegible]	15.77	1.2	15.50	2.1	15.74	1.3
30	13.57	3.3	13.07	3.4	14.62	[illegible]	15.27	3.1
32	13.22	[illegible]	13.31	2.4	14.01	3.0	13.61	2.6
33	14.52	3.5	[illegible]	[illegible]	14.57	[illegible]	[illegible]	[illegible]
34	12.32	[illegible]	12.43	[illegible]	12.67	3.5	13.00	3.3
35	14.30	4.0	12.60	3.7	14.30	4.0	12.60	3.7
36	12.25	[illegible]	12.81	2.7	12.73	3.1	12.80	3.1
37	[illegible]	4.3	12.35	4.0	[illegible]	4.3	12.35	4.0

Legend ___

$\overline{PR}$ Average Priority - all transactions, weight 1

s_r Standard deviation of observed value of $\overline{PR}$

$\overline{PU}$ Average Priority - all transactions, units weighted

s_u Standard deviation of observed values of $\overline{PU}$

$\overline{PR}^*$ Average Priority - transactions less special ships

s^*_r Standard deviation of observed values of $\overline{PR}^*$

$\overline{PU}^*$ Average Priority - transactions less special ships, units weighted

s^*_u Standard deviation of observed values of $\overline{PU}^*$

Table 7

Calculated Average Priorities

Table 17 following gives the rank numbers of all the sample items according to:

1) E

2) Factors of E

3) Average Priorities

4) AHS Load List Quantity

The AHS load list quantity was originally included at the suggestion of Lcdr. G. D. Frost who felt that high load list quantity would imply high essentiality. At that time it was not known that the AHS Load List quantity was equal only to the total AHS past demand experience for the two most recent years. In the end, the AHS load list quantity rankings and subsequent comparisons yielded results almost identical to those achieved with the SRI E and tend to validate:

1) the use of predicted weekly demand based on an assumed demand distribution rather than a demand history, and

2) the use of fleet ships (AHS customers) as the data source for military essentiality rankings to be used for comparisons with system-wide rankings.

Ranking Characteristics

Item	E	C	D	VD	$\overline{PR}$	$\overline{PW}$	$\overline{PR^*}$	$\overline{PW^*}$	ALQ
[illegible]	1[illegible]	[illegible]	1[illegible]	[illegible]	14	14	21	1	6
2[illegible]	2	[illegible]	11	11	6	1	1	1	18
3[illegible]	5	[illegible]	11	12	6	10	7	[illegible]	22
[illegible]	[illegible]	[illegible]	10	[illegible]	6	[illegible]	5	14	10
3[illegible]	[illegible]	[illegible]	[illegible]	13	5	7	7	[illegible]	12
[illegible]	[illegible]	[illegible]	1	[illegible]	14	12	15	[illegible]	1[illegible]
3[illegible]	9	10	[illegible]	10	1	2	1	2	1[illegible]
27	[illegible]	[illegible]	13	11	10	19	10	17	14
33	10	11	15	15	5	3	4	3	15
3[illegible]	11	6	5	4	13	11	13	10	8
3[illegible]	12	12	[illegible]	20	11	15	12	12	12
3[illegible]	13	16	[illegible]	[illegible]	23	22	20	21	6
05	14	14	10	14	15	12	22	18	5
0[illegible]	15	20	16	22	20	23	23	23	23
24	16	17	11	17	21	13	19	11	11
22	17	16	7	9	11	17	16	15	7
20	18	22	14	23	7	1	8	13	21
2[illegible]	19	2[illegible]	3	7	16	20	17	20	4
3[illegible]	20	21	12	21	17	3	11	5	17
17	21	15	1	2	22	21	1[illegible]	22	1
30	22	1[illegible]	2	[illegible]	12	14	14	12	3
3[illegible]	23	23	[illegible]	18	[illegible]	[illegible]	6	7	[illegible]

Legend

E CNI - Military Essentiality

C Unit price

D Predicted Weekly Demand

VD Weekly Dollar Velocity

$\overline{PR}$ Average Priority - all transactions weighted one

$\overline{PW}$ Average Priority - all transactions units weighted

$\overline{PR^*}$ Average Priority - Reduced transactions weighted one

$\overline{PW^*}$ Average Priority - Reduced transactions units weighted

ALQ ALC Load List Quantity

Table 2

The Various Rank Numbers of Inventory Items

3. The Rank Correlations.

The methods of rank correlation used in this study are based entirely on the work of Maurice G. Kendall as set forth in his "Rank Correlation Methods." [15] His coefficient of correlation here denoted by the letter T (Kendall uses the Greek tau) has the three conventional properties of such coefficients:

1) For rankings in perfect agreement (i.e. every item has the same rank in both), T = +1, denoting perfect positive correlation.

2) For rankings in perfect disagreement (i.e. one ranking is the inverse of the other), T = - 1, denoting perfect negative correlation.

3) For values of T which lie between + 1 -1, values increasing in absolute value from 0 to 1 correspond to increasing correlation, positive or negative, between the ranks.

Briefly, to compare two rankings, label each ranked item with both rank numbers. Place the items in the natural order of one ranking and look at the sequence of the numbers of the second rankings. Then:

$$T = \frac{2P}{n/2\ (n-1)} - 1$$

where: n = the number of items being ranked

P = the sum of the quantity of items,

following each item, which are larger numbers.

In the natural order, all the items following each item are all larger. Thus for n such rankings, the maximum value for S will correspond to the natural order and will be $(n-1) + (n-2) + \ldots + 1 = \frac{1+(n-1)}{2}(n-1) = \binom{n}{2}(n-1)$.

Tied ranks, which require special procedures tending always to increase the value of S, are here resolved simply by considering additional digits in the calculation of the E values or average priorities. Two ties in the rankings by AFS load list priorities were resolved arbitrarily after determining that the different possibilities did not produce significantly different results.

T is used to decide upon the independence or non-independence of two rankings of a set of items as follows:

1) An appropriate number, K, between zero and one is chosen. If T exceeds K in size (i.e. $|T| > K$) one decided against independence (i.e. one concludes that the sample displays "significant" evidence of non-zero correlation between the rankings).

2) The number K is selected so that if the two rankings are not correlated, one will so de-

cide with high probability, ($1-\alpha$). Thus α is the probability of a mistaken declaration of dependence (alpha error).

For n greater than 10, the distribution of the T statistic under the hypothesis of independence of the rankings is approximately normal. The distribution is tabled for n between 4 and 10.

Table 9 following gives the correlation coefficients T for the chosen comparisons.

T For the Correlation

	E	c	cD	D	AMS
PR	+.34	+.20	-.25	-.47	-.26
PU	+.32	+.16	-.30	-.45	-.38
PR*	+.26	+.16	-.11	-.41	-.42
PU*	+.33	+.26	-.21	-.36	-.42
E					-.34

Legend T = correlation coefficient

Table 9

Results of Rank Correlations

F. Preliminary Interpretation of the Results.

If α (the probability of rejecting the hypothesis of independence when it should be accepted, alpha error) is chosen to be .3, then all of the 21 T values shown in Table 9 except one ($\overline{PR}$*--cD) would lead to the decision of some dependence between the rankings.

If α is chosen to be .2 then all the 21 T except those associated with the

$\overline{PU}$ - c,

$\overline{PR}$* - c, and

$\overline{PR}$* - cd

comparisons indicate dependence..

If α is chosen to be .1 then all the T associated with the E, D and AKS comparisons indicate dependence (12 of 21).

Finally, an α as low as .02 would lead to a decision of dependence for 8 of 21 comparisons, namely:

$\overline{PR}$ - E,

$\overline{PU}$ - AKS,

$\overline{PR}$* - AKS,

PU* - AKS, and

all D comparisons.

Two secondary questions are best answered now:

1) What was the influence of [illegible]

[illegible]

[illegible]

[illegible]

2) [illegible] type correlations.

2) What was the difference between PR and PU type correlations?

A. 1) The PU type correlations were slightly larger in size than the PR type.

We may then say that the limited experiment did not serve to distinguish between the different procedures which were used to define the sample --- nor did it point toward any "better" alternatives.

In general, this experiment indicated the existence of a significant correlation between the SRI [illegible] and

1) average priorities

2) the inverse of predicted demand, and

3) the inverse APL load list quantity, or demand history.

PART V - CONCLUSIONS AND RECOMMENDATIONS

[illegible] of a [illegible] theory, [illegible], is exactly [illegible] utility theory: The development of a [illegible] utility functions. "There can be no question that it is extremely difficult to determine a person's utility function [illegible] time." [16]

An experimental procedure [illegible] field of limited success in this field is the limitation of the problem to one utility rating [illegible] "[illegible]" items or causes and the development of the ratings by [illegible] the decision makers in terms of overall performance. This is the technique of the George Washington University - Office of Naval Research projects for the development of allowance lists for THRESHER class submarines and the Polaris missile system. The literature of utility theory indicates that this technique may well succeed for the limited scope of these projects, but cannot practically be expected to be adequate for use in a field as large as system-wide supply management. In addition to the sheer magnitude of the task, the inconsistency of human choice in

response to utility questioning and the inability of humans to discriminate among more than a few distinct levels in any utility dimension seem to be the insurmountable barriers. [16 - pp.35 - 37]

Fraction coding for codes R and X, aeronautical provisioning, the "flyaway kit" program and the methods of the ordnance stock office (OSO) and the ships parts control center (SPCC) appear to be fundamentally similar to the above technique from a utility theoretical point of view, with the added complexity of having removed the task of "question answering" from the "players" (users) and having placed it in the hands of a separate group - technicians within high supply echelons.

The E of the SRI-ESO model can be viewed as a utility function "imposed upon the game" by rationale. From a utility theoretic standpoint, the acceptability of this solution to the utility function problem rests solely upon the acceptability of the rationale, and is, in this case, divorced from any utility appraisal by the "players" either before or after the "game" (USE).

In the language of utility theory, one can "suppress" this perplexing problem by observing the player's past actions while "playing the game" and recording therefrom his "true" (demonstrated)

utility function. [16 - pp 15-16] It is the contention of this thesis that the proposal of Part III is just such a technique, inasmuch as the priority system is a continuous system-wide field use appraisal of the relative utility of each item. Admittedly, the priority system was not designed for any such use, but the requisite theoretical framework for the solution to this problem appears to be present. If such is not the case, the problem may well warrant a new system to be appended to the requisitioning procedure and designed to attack just this problem.

<u>CONCLUSIONS.</u> From the limited experiment reported in this paper, only a few general conclusions can be drawn due to sampling limitations. One can only say that, with respect to items of electronics tubes fraction coded F, there is strong evidence of positive correlation between the results yielded by SRI-ESO'S E and the priority - based proposal of Part III. It appears that both methods are ranking items by the same characteristic, and that this characteristic may well represent the intended meaning of "relative military essentiality."

When the component factors of E were examined separately, a possible positive correlation was

indicated between the results of the priority proposal and item cost C; on the other hand, it seems certain that a negative correlation exists between priority results and demand rate D. A rough interpretation of these facts is that, whereas SRI personnel believe that E = C is the rational point of departure for further study of the nature of E, it would appear that $E = \frac{1}{D}$ is a more promising starting hypothesis. The argument seems strongly supported that the more militarily essential items are the more durable and reliable or are well provided for locally.

The fact that a negative correlation is indicated between the priority-based results and the items' AKS load list quantities is no surprise in view of the fact that the AKS load is developed from fleet usage data and is therefore a direct function of demand. If there exists, in turn, a negative correlation between demand rate and true military essentiality, then the more militarily essential an item is, the less likely it is to be found on board an AKS deployed with the fleet.

<u>RECOMMENDATIONS</u>. In order to test more thoroughly the existence of a significant correlation between the results of the two methods for electronic tubes, another, larger experiment is

needed to: 1) reduce the sampling costs and 2) increase the sample space. This much larger sample, randomly selected from all electron tube items so that all Project codes are adequately represented, might establish a statistical distribution of priority assignments for each item, enabling results to be stated with greater statistical confidence. [illegible] is a random variable (since D is a random variable) and [illegible] is the arithmetic mean of priority assignments. The distribution of demand is assumed with confidence in all inventory models currently in use at the [illegible]DCP'S. If an assumption of the distribution of the mean priority can be properly substantiated, one could expect to postulate and examine functional relationships greatly more revealing than the non-parametric inferences to which the present study is limited.

In the interests of sample size and randomization additional data sources must be added, including, it is recommended, MSC vessels, coastal supply depots and shipyards so that sufficient transactions are obtained for low demand items to make more precise statistical statement possible. The authorization of the Bureau of Supplies and Accounts would be needed to make this experiment

possible.

This experiment should exemplify an economical method of approach to further understanding of the nature of essentiality, especially with regard to differentiating the various contributions to essentiality of different item characteristics. If the experiment indicates a high positive correlation between NAV-ASO's E and the priority-based results, throughout all fraction codes, then the rationale underlying E would be fortified by whatever utility theoretical soundness can be ascribed to the priority examination. Since E is cheaply and quickly obtainable, it would be continued in use. If, on the other hand, there proved to be a limitation of correlation as the experiment was extended beyond fraction code F, then new functions of cost and demand similar to the present E could be sought which do correlate with priority behavior. Such a new function could then be tested by synthetic item activity simulation to insure adequacy of order-level protection in all ranges of dollar velocity.

If no such new function could be found, then a choice would have to be made between the rationale of E and the rationale underlying the mean priority proposal, weighing into the decision the greater cost of the latter.

Important to the choice is the fact that the [illegible] form of E was confirmed [illegible] by one-time curve fitting in 1959. The cost of an item is subject to changes in the nationwide economy which have no relation to military essentiality (indeed, the operation of the model can itself [illegible] re- [illegible]). [illegible] radically affected by policy changes involving active fleet quantities, fleet readiness, and the disposition of the reserve fleets. Who can be sure that the present form of E provides continuing order-level protection under conditions of price and demand fluctuation?

The testing of priority-based results for acceptable order-level protection through activity simulation [illegible] be a part of the design process.

<u>OPPORTUNITIES FOR FURTHER STUDY</u>. In addition to the questions answerable by the experiment recommended above, several longer questions present themselves:

- Can the priority proposal be extended beyond electronics tubes and even beyond electronics repair parts? Would this method provide a truly system-wide utility ranking of electronics parts

among ships machinery parts and ordnance parts, which might someday provide a basis for a system of fund allocation among the supply demand control points?

- Should the priority system be re-designed in light of this additional role, to reduce the effect of anomolous behavior and to yield numbers usable as essentiality indices with a minimum of scale transformation?

- Viewing the issue from another point of view, if there is someday developed a scale of military essentiality that is widely considered to be rational and acceptable, then should not the priorities in the mission - end use table be re-arranged to reflect essentiality? This would mean the redesign of the system to maximize rank correlation of numerical priority with military essentiality.

In conclusion, further progress in the management of inventory by mathematical model awaits the development of an acceptable method for the essentiality rankingof stock items. Although the limited experiment reported in this paper could neither confirm nor dismiss the appropriateness of the priority proposal of Part III, the strong suggestion is present in the results that this method may be a solution to the problem in

its own right or, more likely, may lead to confirmation of a more economical but adequately reliable formula solution, such as E. The prime result of this experiment seems clearly to be a justification for further experimentation.

BIBLIOGRAPHY

1. Supply Support Of The Navy. Bureau of Supplies and Accounts; Department of the Navy, NAVSANDA publication 340, 15 Sept. 1957.

2. Stock Control Policy - Aviation Supply Office. S. G. Allen and T. R. Broida, Stanford Research Institute Project No. IU-2109, March, 1958.

3. Advanced Stock Control Procedures - Electronics Supply Office. T. R. Broida, R. H. Davis, S. G. Allen; Stanford Research Institute Project No. IU-2109, January, 1959.

4. The Development and Implementation of Advanced Inventory Control Procedures. P. G. Butterfield, et al. Stanford Research Institute Project No. IU-2109, December 1960.

5. Planning Production, Inventories and Work Force; Holt, Modigliani, Muth and Simon. Prentice-Hall, 1960.

6. Optimal Inventory Policy; Arrow, Harris and Marschak. Report P-189 Rand Corp. Revised 16 November 1950.

7. Theory of Inventory Management; Whitin. Princeton University Press, 1957.

8. Bureau of Supplies and Accounts Manual

9. Provisioning of Aeronautical Articles; U. S. Navy Aviation Supply Office, June 1958.

10. Inventory Control of Low Demand Items; Cdr. H. F. Mills Sc USN. Project A-1-A Ships Parts Control Center, 20 February, 1959.

11. Ordnance Supply Office Unpublished Report to Supply Demand Control Point Seminar, 13 June, 1960.

12. Military Worth (Essentiality); The George Washington University Logistics Research Project NR. 047001 (Office of Naval Research) 1958.

13. Department of the Navy, Special Projects Office Instruction 5000.1 of 26 March 1960, 5000.2 of 5 May 1960.

14. A Method of Estimating Spare-Part Essentiality; H. W. Karr. Rand Paper P-1064, April 17, 1957.

15. Rank Correlation Methods; M. G. Kendall. London, C. Griffin, 1948.

16. Games and Decisions; R. D. Luce and H. Raiffa, New York, John Wiley & Sons, Inc., 1957.

APPENDIX

BUSANDA MANUAL PARA 33026-6

6. REQUEST PRIORITY (PRIORITY DESIGNATOR) (EFFECTIVE 1 JANUARY 1960)

a. Assignment of Priority. Requests for material will be assigned a numerical priority designator which will reflect the relative military essentiality of the intended use of the requested materid, as indicated by the end use definition code. The numerical priority designator expresses the relationship between mission category and the applicable end use definition code and will range with diminishing importance from number 1 through 37. The requestor will apply the assigned mission category and end use code appropriate to his activity to the Mission Category End Use Code Conversion Table (see subpar. f.), to determine the applicable numerical priority designator. Priority designators are designed to provide a means for supply and transportation activities to process requests and shipments in accordance with military importance and urgency of need. The system is intended to determine material issue policies and efficient employment of transportation and communication capabilities. To maintain the integrity of the priority system, the quantity of material requested

will be limited to that amount necessary to satisfy the requirement that initiated the request.

b. Responsibility for Assignment of Priority

(1) Responsibility

(a) General. Commanding officers are responsible for the proper assignment of priority designators and realistic dates that the material is required (DMR). The authority to redelegate is restricted. In redelegating there will be a clear indication of the necessity for conscientious compliance with the procedures covering the assignment of priorities.

(b) Priority Designators 1 through 7. Commanding officers, officers in charge, the senior officer acting in behalf of the commanding officer or officer in charge during his absence or incapacity, or one officer designated in writing will personally sign all requests bearing priorities 1 through 7. This authority may not be redelegated.

(c) Priority Designators 8 through 10. Commanding officers and officers in charge may assign in writing to key officer personnel the authority to autherize requests bearing priorities 8 through 10.

(d) Priority Designators 11 through 37. Commanding officers and officers in charge may assign to key personnel the authority to authorize requests bearing priorities 11 through 37.

(2) Review. Primary responsibility for the correct use of the Material Requirements Priority System is a function of command and requires overall review to insure proper understanding and application. Fleet and overseas shore activity requests will be reviewed as directed by the appropriate fleet commander. Periodically, supply activities will be requested by competent authority to furnish statistical data on incoming requisitions. Such requests will be forwarded via the Bureau of Supplies and Accounts (Assistant Chief for Supply Management). Administrative inspections of the retained requisition files will disclose whether or not priority designators are being assigned properly.

c. Mission Category

(1) General. Mission categories will be prescribed by appropriate authority for ships, units, and activities according to the relative military importance of the mission assigned. This designation is in the form of a number ranging from 1 through 5. The authority to

assign a mission category may be delegated or withheld in accordance with subpar. (2) or other superseding directives, as required by the existent circumstances; however, it is intended that authority be retained at the highest practical level. Units within a force may be assigned different mission categories, either of higher or lower classification, by the appropriate military commander. Unless a ship, unit, or activity is otherwise advised, mission category 5 applies. The Fleet Commanders in Chief; Commander Military Sea Transportation Service; Chief of Naval Air Training; Chief of Naval Material; Chief of Naval Research; the Office of the Comptroller of the Navy; and Chiefs of all Bureaus will promulgate the necessary directives to insure the assignment of mission categories on an initial and continuing basis for all ships, units, and activities under their military command or management control. Ordinarily, changes in mission categories for fleet units will be accomplished at the time naval operational control of a unit or individual ship passes from one operational control authority to another.

(2) Specific Authority

(a) General. Authority to assign a mission

category may be delegated or withheld in accordance with the criteria in subpars. (b) through (f).

(b) Mission Category 1. Mission category 1 is reserved for specific assignment by the Secretary of the Navy, Chief of Naval Operations, or Fleet Commanders in Chief to insure the accomplishment of missions of overriding importance. Authority to assign this mission category will not be delegated.

(c) Mission Category 2. Mission category 2 may be assigned to combatant units and units furnishing direct support to combatant units that comprise the primary offensive and defensive forces, whose mission is of vital importance and directly affects national security. Authority to assign under this criterion is granted to Fleet Commanders in Chief; Commander Military Sea Transportation Service; and naval component commanders of unified and specified commands. In addition, assignments may be made to such other units or activities as may be specifically assigned by the Secretary of the Navy, Chief of Naval Operations, or Fleet Commanders in Chief. As required, Fleet Commanders in Chief may delegate the authority to assign this mission category to Fleet Commanders, Task

Force Commanders, and Type Commanders.

(d) Mission Category 3. Mission category 3 may be assigned to the following:

1. Active fleet units that supplement or indirectly support the primary offensive and defensive forces in mission category 2.
2. Activities providing direct industrial or logistic support to active fleet forces.
3. Combatant and support forces otherwise assigned mission category 4 or 5 preparing to deploy on a tactical or strategic mission assignment within 30 days; this time period may be varied by the appropriate fleet commanders to allow flexibility.

Authority to assign this mission category is granted to Fleet Commanders in Chief; Commander Military Sea Transportation Service; Chiefs of Bureaus and Offices; and naval component commanders of unified and specified commands. As required, Fleet Commanders in Chief may delegate the authority to assign this mission category to Fleet Commanders, Task Force Commanders, and Type Commanders.

(e) Mission Category 4. Mission category

4 may be assigned to the following:

1. Training units and units engaged in scheduled training operations in preparation for deployment on a tactical or strategic assignment; units of the active fleet force inside continental United States and the Pearl Harbor area assigned scheduled overhaul, upkeep, or repair.

2. Activities providing industrial or emergency logistic support to active fleet forces.

Authority to assign this mission category is granted to Fleet Commanders in Chief; Commander Military Sea Transportation Service; Fleet, Force, and Type Commanders; naval component commanders of unified and specified commands; and Chiefs of Bureaus and Offices.

(f) Mission Category 5. All other units and activities, active and reserve, are assigned mission category 5.

(3) Special Programs and Projects. The Secretary of the Navy or the Chief of Naval Operations may assign a specific mission category to major Navy programs, projects, or special operations in keeping with the relative military importance of such undertakings. The

priority designator for material requirements of such programs, projects, or special operations will be determined by the use of the mission category assigned, together with the end use definitions.

d. Definitions

(1) Primary Equipment. Primary equipment is equipment essential to and employed directly in the accomplishment of assigned operational mission and tasks.

(2) Auxiliary Equipment. Auxiliary equipment is equipment which supplements or takes the place of primary equipment should the primary equipment become inoperative. An auxiliary power generator is illustrative of such equipment.

(3) Collateral Equipment. Collateral equipment is equipment not essential to the performance of assigned operational missions and tasks. Included are administrative and habitability equipments; such as, typewriters, soda fountains, drinking fountains, and movie projectors.

(4) Material. Material is the general term used to encompass consumable materials, ammunition, repair parts, instruments, and equipments.

e. End use Code

(1) General. The end use definition tables contained in subpars. (2) through (9) encompass the material requirements of all Navy users and express material requirements which reflect a consideration of equipment application, the military significance of equipment, and the urgency of material requirements. Subparagraphs (2) through (8) are special purpose definitions, expressing the requirements of specific types of units and activities. Subparagraph (9) is a general purpose definition which groups the requirements of all other activities not specifically provided for and those nonindustrial requirements common to all shore activities. In certain instances, the use of more than one table will be required. For example, shipyards will use subpar. (4) for industrial purposes and subpar. (9) for nonindustrial purposes.

(2) Table of End Use Definitions for Ships. The following table of end use definitions is established for ships:

End use code	End use definitions
A	Material required to effect emergency replacement or repairs to a ship's hull,

propulsion plant, armament, catapults, or other primary equipment system which has been damaged or rendered inoperative to the extent that the ship is unseaworthy or otherwise incapable of performing assigned operational mission and tasks. Requirements of this nature are of such consequence as to dictate an immediate report, in accordance with NWIP 10-1, par. 610. Replacement of complete missiles or material required to effect emergency repairs to missiles which have been damaged, rendered inoperative or unsafe, and the number of missiles involved is such that the firing capability is reduced below authorized levels.

Material required on an emergency replenishment basis without which the ship cannot perform its assigned operational mission and tasks. For example, emergency need for teletype paper for deployed AGC, hydrographic charts for deployment from one overseas area to another under emergency conditions or general war, or a requirement for landing nets by a deployed amphibious vessel. Requirements of this nature are of such consequence as to dic-

tate an immediate report to the appropriate commander.

B Material required to effect emergency replacement or repairs to auxiliary equipment systems, such as an auxiliary power system, without which the ship can operate temporarily as a effective unit and continue to perform its assigned operational mission and tasks.

Material urgently required and without which serious personal hazard will result. This includes asbestos suits for crash crews, protective clothing for underwater demolition teams, etc.

Replacement of complete missiles or material required to effect emergency repairs to missiles which have been damaged, rendered inoperative, or unsafe. In either case the firing capability has not been reduced below authorized firing levels.

C Material required to effect emergency repairs or replacement and make ready for sea collateral equipment, or systems not contributing to operational effectiveness or safety of the ship.

Material immediately required for emergency deployment.

Material required for interim replenishment of Fleet Issue Load List or Tender and Repair Ship Load List stocks in order to meet anticipated requirements for which on hand stocks are insufficient and on order material will not be delivered in sufficient time to augment existing stocks.

D Material required in preparation for scheduled deployment.

Material required to replenish stocks during deployment in order to maintain readiness in accordance with fleet stock level policies.

Material required for scheduled maintenance of specific equipments.

E Material required for initial outfitting and filling of allowance and load list additions.

Material required for routine replenishment of Fleet Issue Load List or Tender and Repair Ship Load List stocks.

Stock replenishment of items which have

been specifically designated by cognizant inventory managers as justifying premium handling by virtue of repairability or other economic considerations in accordance with prescribed criteria. For example: this end use is applicable to fraction code Q aeronautical items encompassed within Aviation Supply Office high priority program. Priority designator 20 will be assigned to such requirements.

F Routine requirements not otherwise provided for.

X Medical or disaster supplies or equipment required immediately for prolonging life in case of critical injury, fatal disease, or calamity. When this end use code is employed, a priority designator 3 will be assigned.

(3) Table of End Use Definitions for Aviation Units. The following table of end use definitions is established for aviation units:

End use code	End use definitions
A	Material, including immediate or urgent action aircraft service changes, required

for immediate installation or use to effect emergency repairs or replacement for aircraft (in operating categories A1 through A9) out of commission or not capable of safe flight. The following criteria must be met in order to justify this end use: one-half or more of the particular model aircraft assigned to a squadron must be out of commission or grounded for the same equipment, repair part, etc.; and the deficiency is of such a nature as to dictate an immediate report to the appropriate commander.

Replacement of complete missiles or material required to effect emergency repairs to missiles which have been damaged, rendered inoperative, or unsafe, and the number of missiles involved is such that firing capability is reduced below authorized levels. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.

Material required on an emergency replenishment basis without which the operating unit cannot perform its assigned operational mission and tasks, for example, tar-

geting data or navigational charts for scheduled operations under emergency conditions. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.

B Material including immediate or urgent action aircraft service changes required to effect emergency repairs or replacement to aircraft (in operating categories A1 through A9) without which the aircraft is out of commission and not capable of safe flight or incapable or performing its primary mission even though capable of safe flight.

Replacement of complete missiles or material required to effect emergency repairs to missiles which have been damaged, rendered inoperative, or unsafe. In either case, the firing capability has not been reduced below authorized firing levels.

Material urgently required and without which serious personal hazard will result. For example, this would include urgently required mandatory personal flight equipment.

C Material required to effect emergency replacement or repair of specific units of inoperative maintenance support equipment necessary to carry out the assigned mission.

Material not falling in end use codes A or B, including aircraft service changes, required to effect emergency repairs or replacement to specific aircraft or missiles required to avert disruption or delay of aviation fleet or training operations, maneuvers or exercises.

Material immediately required for emergency deployment.

D Material required in preparation for scheduled deployment.

Material required to replenish stocks during deployment in order to maintain readiness in accordance with fleet stock level policies.

Material required for scheduled maintenance of a specific aircraft, missile, or maintenance support equipment.

E Stock replenishment of items which have

been specifically designated by cognizant inventory managers as justifying premium handling by virtue of repairability or other economic considerations in accordance with prescribed criteria. For example, this end use is applicable to fraction code Q aeronautical items encompassed within the Aviation Supply Office high priority program. Priority designator 20 will be assigned such requirements.

Material required for initial outfitting and filling of allowance list addition.

F Routine requirements not otherwise provided for.

X Medical or disaster supplies or equipment required immediately for prolonging life in case of critical injury, fatal disease, or calamity. When this end use code is employed, a priority designator 3 will be assigned.

(4) Table of End Use Definitions for Shipyards, Ship Repair Facilities, and submarine bases (Industrial Use Only). The following table of end use definitions is established for shipyards, ship repair facilities, and subma-

rine bases (industrial use only). (See subpar. (9) for nonindustrial requirements.)

End use code	End use definitions
A	Material required to effect emergency or voyage repairs to a ship's hull, propulsion plant, armament, catapults, or other primary equipment system which has been damaged or rendered inoperative to the extent that the ship is unseaworthy or otherwise incapable of performing assigned operational mission and tasks. Requirements of this nature are of such consequence that a casualty report will have been submitted by the ship in accordance with NWIP 10-1, par. 610. The mission category of the ship will be used to determine the priority designator.
	Material required to effect emergency repairs or replacement to essential physical facilities of the industrial activity without which the activity cannot carry out its primary mission of ship conversion and repair. Requirements of this nature are of such consequence as to preclude meeting the repair or construction schedule of

operational commanders, and dictate the submission of an immediate report to the appropriate commander.

B Material required to effect emergency or voyage repairs to auxiliary shipboard equipment systems, such as, an auxiliary power system without which the ship can operate temporarily as an effective unit and continue its assigned operational mission and tasks. The mission category of the ship will be used to determine the priority designator.

Material required to eliminate an existing work stoppage in scheduled manufacture, repair, overhaul, or replacement of primary equipment systems required for safety at sea or directly used in performance of ship's assigned operational mission and tasks.

Material required to eliminate an existing work stoppage in the manufacture, rework, repair, or overhaul of items designated as being in critical supply by the cognizant inventory manager.

C Material required to effect emergency or

voyage repairs and make operative and ready for sea collateral equipment systems not contributing directly to the operational effectiveness or safety of the ship. The mission category of the ship will be used to determine the priority designator.

Material required to effect emergency replacement or repair of specific units of inoperative maintenance support equipment necessary to carry out the assigned industrial mission.

D Material required to effect scheduled repair, replacement, overhaul or construction of ship's hull, propulsion plant, armament, catapults or other primary equipment system required for safety at sea or directly used in performance of the ship's assigned operational mission and tasks.

Material, the lack of which would delay scheduled delivery of a ship, or in peacetime, would result in substantial economic disadvantage to the Government.

E Material required to effect the scheduled repair, replacement, overhaul of auxiliary equipment systems required directly for

performance of secondary missions or required to maintain at sea endurance.

Stock replenishment of items which have been specifically designated by cognizant inventory managers as justifying premium handling by virtue of repairability and other economic considerations in accordance with prescribed criteria. For example, this end use is applicable to fraction code Q aeronautical items encompassed within the Aviation Supply Office high priority program. Priority designator 20 will be assigned such requirements.

F Material required for scheduled manufacturing or repair of local or system stocks of operating equipments.

All other material required for installation or use to effect repair, replacement, overhaul, construction, or conversion of ships except those requirements covered in end use code H.

H Requirements to effect alterations to Reserve Fleet ships other than for activation.

X Medical or disaster supplies or equipment required immediately for prolonging life in case of critical injury, fatal disease, or calamity. When this end use code is used, a priority designator 3 will be assigned.

(5) Table of End Use Definitions for Aircraft and Missile industrial activities or units (Industrial Use Only). The following table of end use definitions is established for aircraft and missile industrial activities or units (industrial use only). (See subpar. (9) for nonindustrial requirements.)

End use Code	End use definitions
A	Material, including immediate or urgent action aircraft service changes, required for immediate installation; or use to effect emergency repairs, or replacement for aircraft, or missiles out of commission or not capable of safe flight. The following criteria must be met in order to justify this end use: one-half or more of the particular model aircraft or missile being reworked, overhauled, or repaired must be out of commission for the same equipment

repair part, etc., and the deficiency is of such a nature as to dictate an immediate report to the appropriate commander.

Material, including immediate or urgent action aircraft service changes, required for immediate installation or use on an aircraft or missile which is incapable of safe flight and has been grounded pending incorporation of such changes or modification. The following criteria must be met in order to justify the assignment of this end use code: the grounding of the aircraft, missile model, or configuration has been directed by the appropriate commander pending incorporation of such modification or change, upon completion of work the aircraft or missile will be returned to a fleet command, and the affected aircraft or missile has been designated as critical by the appropriate commander.

Material required to effect emergency repairs or replacement to essential physical facilities of the industrial activity without which the activity cannot carry out its primary mission of aircraft or missile over-

haul or repair. Requirements of this nature are of such consequence as to preclude meeting assigned overhaul or repair schedules and dictate the submission of an immediate report to the appropriate commander.

B Material, including immediate or urgent action aircraft service changes, required to effect emergency repairs, or replacement to an aircraft or missile without which the aircraft or missile is out of commission and not capable of safe flight.

Material, including immediate or urgent action aircraft service changes, required for an aircraft or missile to effect emergency repairs or replacement without which the aircraft or missile cannot perform its primary mission even though capable of safe flight.

Material, including immediate or urgent action aircraft service changes, required to eliminate an existing work stoppage in performing manufacture, rework, repair, or overhaul required to place an aircraft or missile in operating condition. Scheduled delivery of aircraft or missile to the

fleet will be delayed pending material receipt.

Material required to eliminate an existing work stoppage in manufacture, rework, repair, or overhaul of items designated as being in critical supply by the cognizant inventory manager.

Material required to eliminate an existing work stoppage in performing scheduled engine overhauls.

C Material required to effect emergency replacement of repair of specific units of inoperative maintenance support equipment necessary to carry out the assigned industrial mission.

D Material required to place the aircraft or missile, undergoing overhaul or interim rework, in operating condition. Nonreceipt of material by the date material is required will result in work stoppage or cause a delay in scheduled delivery of aircraft or missile to the fleet.

Material required to eliminate an existing work stoppage in scheduled overhaul of noncritical items for stock.

Material required to prevent imminent aircraft, missile, or engine overhaul work stoppage or disruption of aircraft or missile component overhaul, repair, or modification schedules for aircraft or missiles.

E Material required for initial outfitting and filling of allowance list additions.

Stock replenishment of items which have been specifically designated by cognizant inventory managers as justifying premium handling by virtue of repairability and other economic considerations in accordance with prescribed criteria. For example, this end use is applicable to fraction code Q aeronautical items encompassed within the Aviation Supply Office high priority program. Priority designator 20 will be assigned such requirements.

F Material required to effect scheduled repair, replacement, and overhaul of specific aircraft, missile or maintenance support equipments in use.

Repair parts or materials required for scheduled manufacturing or repair of local

or system stocks of airborne or shop equipments.

N Medical or disaster supplies or equipment required immediately for prolonging life in existing case of critical injury, fatal disease, or calamity. When this end use code is employed, a priority designator 3 will be assigned.

(6) Table of End Use Definitions for Industrial Activities not Otherwise Provided for (Industrial Use Only). The following table of end use definitions is established for industrial activities not otherwise provided for (industrial use only).

End use Code	End use definitions
A	Material required on an emergency basis to eliminate or prevent an imminent extreme safety hazard. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.
	Material required to effect emergency repairs or replacement to essential physical facilities of the industrial activity with-

out which the activity cannot meet production schedules for items which would preclude a ship or unit of the operating forces from performing assigned operational mission and tasks. Requirements of this nature are of such consequence as to dictate the submission of an immediate report to the appropriate commander.

Material required on an emergency basis for the manufacture, repair, overhaul, alteration, or rework of items, the lack of which would preclude a ship or unit of the operating forces from carrying out its assigned operational mission and tasks. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.

B Material required to eliminate an existing work stoppage in manufacturing, repair, overhaul, reworking, or alteration of items designated as being in critical supply by the cognizant inventory manager.

Material required to eliminate an existing work stoppage in performing manufacture, repair, overhaul, alteration, or rework of primary equipment systems directly used in

performance of operating forces assigned operational mission and tasks.

C Material required to effect emergency replacement or repair of specific units of inoperative maintenance support equipment necessary to carry out the assigned industrial mission.

D Material required to eliminate an existing work stoppage in scheduled manufacture, repair, overhaul, alteration, or rework.

Material required in peacetime, the lack of which material would result in substantial economic disadvantage to the Government.

E Stock replenishment of items which have been specifically designated by the cognizant inventory managers as justifying premium handling by virtue of repairability or other economic considerations in accordance with prescribed criteria. For example, this end use is applicable to fraction code Q aeronautical items encompassed within the Aviation Supply Office high priority program. Priority designator 20 will be assigned such requirements.

Material required for initial outfitting and filling of allowance and load list additions.

F Repair parts or materials required for manufacture, repair, overhaul, alteration, or rework of local or system stocks.

M Medical or disaster supplies or equipment required immediately for prolonging life in case of critical injury, fatal disease or calamity. When this end use code is employed, a priority designator 3 will be assigned.

(7) Table of End Use Definitions for Research and Development Activities (Research and Development Only). The following table of end use definitions is established for research and development activities (research and development only). (See subpar. (9) for station maintenance and routine housekeeping requirements.)

End use Code	End use definitions
A	Material required on an emergency basis for immediate installation or use without which a research activity cannot carry

out its primary mission with regard to projects on the Military Urgency List. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.

Material required to effect emergency repairs or replacement to essential physical facilities of the activity without which the activity cannot carry out its primary mission with regard to assigned projects on the Military Urgency List. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.

B Material required to eliminate an existing work stoppage on approved projects.

C Material required to effect emergency replacement or repair of specific units of inoperative maintenance support equipment necessary to accomplish approved projects.

D Material, including instruments, required for the continuation of approved projects when nonreceipt of such material prior to the date the material is required will result in work stoppage.

E Stock replenishment of items which have been specifically designated by cognizant inventory mangers as justifying premium handling by virtue of repairability or other economic considerations in accordance with prescribed criteria. For example, this end use is applicable to fraction code Q aeronautical items encompassed within the Aviation Supply Office, high priority program. Priority designator 20 will be assigned such requirements.

F Material, including instruments required for scheduled projects including the construction, modification, and repair of equipment, and other technical facilities required for such projects.

X Medical or disaster supplies or equipment required immediately for prolonging life in case of critical injury, fatal disease, or calamity. When this end use code is employed, a priority designator 3 will be assigned.

(8) Table of End Use Definitions for Mobile Construction Battalions. The following table of end use definitions is established for mo-

bile constructien battalions:

End use

Code	End use definitions
A	Constructien equipment and instruments required on an emergency basis without which the battalion cannot carry out its assigned operational mission or tasks. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.
	Material required for emergency repairs or replacement te primary construction equipment which has been damaged er rendered inoperative to the extent that the battalion is incapable of performing its assigned operational mission and tasks. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.
	Small arms and ammunition required on an emergency basis without which the battalion cannot operate as an effective work or cembat unit.
	Material required on an emergency basis to construct, alter, rehabilitate, or repair ineperative or unusable essential

physical facilities of a shore activity without which the shore activity cannot carry out its assigned mission and tasks. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.

B Material required to effect emergency replacement or repairs to inoperative equipment which contributes directly to the operational effectiveness of the battalion, but without which the battalion can operate temporarily as an effective unit and continue to perform its assigned operational mission and tasks.

Material urgently required and without which serious personal hazard will result.

Material required to eliminate an existing work stoppage in the construction alteration, rehabilitation, or repair of facilities, systems or plants essential to carry out the assigned operational mission of a shore facility.

C Material required to effect emergency replacement or repairs to specific units of inoperative maintenance equipment neces-

sary to carry out the assigned operational mission of the battalion.

Material immediately required in preparation for emergency deployment.

D Material required to effect scheduled repair, replacement, or overhaul of primary construction equipment required for the battalion to carry out its assigned operational mission and tasks.

Material required in preparation for scheduled deployment.

Material required to replenish stocks during deployment in order to maintain readiness in accordance with fleet stock level policies.

Material required to prevent an imminent work stoppage in the construction, alteration, rehabilitation, or repair of facilities, systems, or plants essential to carry out the assigned mission of a shore facility.

E Stock replenishment of items which have been specifically designated by cognizant inventory managers as justifying premium

handling by virtue of repairability or other economic consideration in accordance with prescribed criteria. For example, this end use is applicable to fractien cede Q aeronautical items encompassed within the Aviation Supply Office high priority program. Priority designator 20 will be assigned to such requirements.

Material required to effect scheduled repair, overhaul, or replacement of other than primary equipment.

Material required for initial outfitting and filling ef allowance list additions.

F Routine requirements not otherwise provided fer.

H Material required to fill allowance deficiencies in reserve battalions, other than for activation.

X Medical or disaster supplies or equipment required immediately for prelonging life in case of critical injury, fatal disease, or calamity. When this end use code is employed, a priority designater 3 will be assigned.

(9) Table of End Use Definitions for Units and Activities not otherwise Provided for Including Definitions Common to all Activities. The following table of end use definitions is established for units and activities not otherwise provided for including definitions common to all activities:

End use Code	End use definitions
A	Material required for emergency repairs or replacement of inoperative essential systems or equipment, such as main power plant, ground control approach system, or aviation fuel farm, without which the activity cannot carry out its primary mission and tasks. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.
	Material required on an emergency replenishment basis without which the unit or activity cannot perform its assigned operational mission and tasks. Requirements of this nature are of such consequence as to dictate an immediate report to the appropriate commander.
B	Material urgently required and without

which serious personal hazard will result.

C Material required for emergency repairs or replacement of inoperative systems or equipments not included in end use code A; such as, auxiliary power systems and machinery used in the upkeep of buildings and grounds.

Material required for interim replenishment of Fleet Issue Load List or Base Load List stock (including allowance list material stocked at overseas activities supporting the fleet) in order to meet anticipated requirements for which on hand stocks are insufficient and on order material will not be delivered in sufficient time to augment existing stocks.

Material immediately required for emergency deployment.

D Material required for scheduled repairs or replacement of essential systems of equipment, such as main power plant, ground control approach system, or aviation fuel farms, without which the activity cannot carry out is primary mission and tasks.

Material required in preparation for scheduled deployment.

E Material required for initial outfitting and filling of allowance and load list additions.

Material required for scheduled repair or overhaul of systems or equipments not included in end use code D.

Activity originated stock replenishment actions and inventory manager directed redistributions of items which have been specifically designated by cognizant inventory managers as justifying premium handling by virtue of repairability and other economic considerations in accordance with prescribed cirteria. For example, this end use is applicable to fraction code Q aeronautical items encompassed within the Aviation Supply Office high priority program. Priority designator 20 will be assigned to such requirements.

Material required for routine replenishment of Fleet Issue Load List or Base Load List stocks.

F Interim stock replenishments.

Inventory manager directed interim redistribution of stocks (use priority desig-

nator 25).

Material required for repair of nonessential physical facilities without which operations could continue but for which repairs are advisable for reasons of efficiency and economy.

G Routine stock replenishment and requirements for day-to-day operations and upkeep.

Inventory manager directed routine redistribution or procurement of stocks (use priority designator 36).

H Material required to fill allowance deficiencies in reserve ships or units other than for activation.

X Medical or disaster supplies or equipment required immediately for prolonging life in case of critical injury, fatal disease, or calamity. When this end use code is employed, a priority designator 3 will be assigned.

f. Priority Designators. The numerical priority designator expresses the relationship between mission category and the applicable end use. All requests for material will be assigned

a numerical priority designator. In determining the numerical priority for a particular requirement, the requestor, utilizing the mission category assigned the ship, will determine the applicable end use code and from the conversion table identify the appropriate priority designator. If passing action is required within the supply system, the originator's priority designator will always be used.

MISSION CATEGORY END USE CONVERSION TABLE
WITH PRIORITY DESIGNATORS

End Use

Mission Category	A	X	B	C	D	E	F	G	H
1	1	3	5	11	17	20	22	30	37
2	2	3	8	12	18	21	23	31	37
3	4	3	9	13	19	24	25	32	37
4	6	3	10	15	26	28	33	35	37
5	7	3	14	16	27	29	34	36	37

g. Assignment of Date Material Required

(1) General. The date on which material is required will be included on material requests assigned priority designators 1 through 20. However, for priorities 1 through 7, the date material is required will be considered as the date of the request unless otherwise indicated. For priorities 21 through 37, the date material is required may be indicated if considered appropriate. The date material is required will

be a date of positive significance, indicating operational deployment, scheduling of overhaul or repair job, etc., and must reflect adequate and effective planning. Supply processing time and the shipping time will not be considered as determining factors in setting the date required. When the material is not desired prior to some known or carefully estimated future date because delivery prior to that date would create a handling or storage problem, i.e., that advance delivery is not acceptable, explanatory remarks will be included to that effect.

(2) Increasing and Terminating Need Information

(a) General. The date indicated as the date on which the material is required indicates the commencement of a need. This need will continue until the material is delivered or until the conditions surrounding the need change in some manner so as to eliminate the need. The methods to be used to transmit the necessary information to the supply activity are described in subpars. (b) through (e).

(b) Increasing Need. If the need for the material will continue with an increasing urgency after the date material required, the letter I will be suffixed to the letters DMR

(DMRI).

(c) Terminating Need. If it is essential that the specified date material required to be met to the extent that the requirement for the material will cease to exist if the date is not met, the requisition will provide for cancellation unless the specified date is met. Such action will be indicated by suffixing the letter S to the letters DMR (DMRS).

(d) Use of Two Dates. If the need for the material commences on one date and continues for a period of time to another known date on which the need will cease to exist, two dates will be placed on the requisition to communicate complete and accurate information to the supplying activity. For example, DMRI 15 July to DMRS 25 July will indicate that the need commenced on 15 July and becomes increasingly urgent until 25 July at which time the need ceases. Only when the need for the material starts and stops on the same date will a single date material required termination date be assigned. Supply activities will attempt to effect delivery prior to the first date material required when two dates are assigned.

(e) Subsequent Purchase Action. If subse-

quent purchase action is necessary for requests not bearing a date material required termination date, the contracting officer, using the assigned date as a guide, is authorized to assign a realistic contract delivery date. For requests bearing date material required termination dates, if the contract delivery date cannot be assigned within the limits of the assigned termination date, the request will be canceled ad the activity submitting the request will be so advised by message or other appropriate rapid communication.

h. Communications

(1) Priority Designators 1 Through 10. Telecommunications including telephone, as appropriate, will be utilized when transmitting requirements assigned priority designators 1 through 10.

(2) Priority Designators 11 Through 20. Telecommunications, or U. S. Mail when appropriate, will be utilized, consistent with command policy, geographical considerations, and date material is required when transmitting requirements assigned priority designators 11 through 20.

(3) Priority Designators 20 Through 37. U. S. Mail or the equivalent not to exclude

transceivers will normally be utilized when transmitting requirements assigned priority designators 21 through 37.

(4) Format of Instructions. For instructions on message format and additional guidelines see par. 33062.